PLASMA PHYSICS ABSTRACTS
1 JANUARY 1966 through 31 DECEMBER 1967

by

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This collection of abstracts represents those plasma physics publications from the University of Iowa during the above period which are considered relevant to N.A.S.A. Grant NGR-16-001-043. Papers directly supported by this grant are marked with an asterisk(*).

Several of the publications listed are of joint authorship with staff members of other laboratories, particularly Oak Ridge National Laboratory.

A. THEORETICAL

1. Parametric Excitation of Transverse Waves in a Plasma
David Montgomery and Igor Alexeff [Oak Ridge National Laboratory, Oak Ridge, Tennessee]
Physics of Fluids, 9, 1362, 1966

It is shown that an externally-imposed, oscillating electric field excites transverse electromagnetic waves propagating perpendicularly to it, in a cold plasma. The mechanism is closely related to the parametric excitation of longitudinal plasma oscillations recently predicted by Aliev and Silin. The problem provides an application of nonsecular perturbation methods, when the equations of motion are expanded in powers of the external electric field. Arbitrarily small perturbations which arise spontaneously in the plasma are amplified by the action of the electric field, for a certain range of the driving frequency. The growth rate of the oscillations is calculated.

2. Scattering of Energetic Particles by Laboratory Plasmas
David Montgomery, Celso Roqúe, and Igor Alexeff [Oak Ridge National Laboratory, Oak Ridge, Tennessee]
Physics of Fluids, 9, 2500, 1966

Possible experiments on the scattering of energetic particles by laboratory plasmas are discussed. Expressions for scattering coefficients in terms of the electric field autocorrelation functions are derived. Sample situations are considered. Whereas incoherent scattering of electromagnetic waves is governed by the charge density autocorrelation function, energetic particle scattering is governed by the electric field autocorrelation function.

3. Parametric Excitation of Alfvèn Waves
D. Montgomery and R. C. Harding
Physics Letters, 23, 670, 1966

It is shown that if a d.c. magnetic field imposed on a plasma is given a small low-frequency modulation, Alfvèn waves may be excited in the plasma through parametric resonance.

4. Numerical Studies of the Nonlinear Vlasov Equation*
Thomas P. Armstrong
Physics of Fluids, 10, 1269, 1967

The nonlinear one-dimensional Vlasov equation is solved numerically as an initial-value problem. The problem is the same as that considered by Knorr, and is related to, but not the same as, various one-dimensional model calculations using charged sheets. The electron distribution is doubly expanded, the spatial part being expanded as a Fourier series and the velocity part as a Gram-Charlier series. In this representation, the Vlasov equation appears as a matrix ordinary differential equation for the expansion coefficients and is first order in the time. Problems considered are nonlinear Landau damping and the development of strongly unstable initial conditions (two-stream instability). In the latter situation, the limiting amplitudes are computed.

5. Asymptotic State of the Two-Stream Instability*
Thomas P. Armstrong and David Montgomery
Journal of Plasma Physics, 1, 425, 1967

Previously reported numerical investigations of the nonlinear Vlasov equation are extended to an intensive study of the two-stream instability. Strongly unstable initial conditions for the one-dimensional electron plasma are followed in time until the state of the plasma has become essentially time-independent. Both the electric field and the distribution function appear to be characteristic of an inhomogeneous equilibrium, as previously conjectured [Armstrong, 1966].

6. Shielding in Anisotropic Plasmas*
Glenn Joyce and David Montgomery
Physics of Fluids, 10, 2017, 1967

The shielding of charges by spatially uniform electron plasmas with non-zero streaming is considered. Both shielding clouds surrounding "test charges" and density-density correlation functions are calculated. The result emerges that the shielding is not of the exponential Debye type, but is of much longer range, falling off in general as some inverse power of the distance.

7. Foundations of Classical Kinetic Theory
David Montgomery
Lectures in Theoretical Physics, Vol. 9C
(W. E. Brittin and A. O. Barut, Editors;
Gordon and Breach, New York, 1967), pp. 15-95

[Review article based on lectures given at 1966
Boulder Summer Institute of Theoretical Physics
--no ABSTRACT]

8. Controlled Landau Damping of Ion-Acoustic Waves
I. Alexeff, W. D. Jones [Oak Ridge National
Laboratory, Oak Ridge, Tennessee], and D. Montgomery
Physical Review Letters, 19, 422, 1967

[No ABSTRACT]

9. Dispersion of Ion-Acoustic Waves
K. Lonngren, D. Montgomery, I. Alexeff, and W. D. Jones
[Oak Ridge National Laboratory, Oak Ridge, Tennessee]
Physics Letters, 25A, 629, 1967

Time-of-flight measurements are made on ion-acoustic waves to determine the dispersion as the frequency increases toward the ion plasma frequency. The wave velocity shows the theoretically predicted decrease. In addition, a second, fast wave is observed, which propagates at frequencies above the ion plasma frequency, in agreement with Sessler's observations. It is suggested that the faster component may be a burst of accelerated ions.

10. A Derivation of the Equation of Brownian Motion from
the Kinetic Equation for Weakly Interacting Gases*
David Montgomery
[Accepted for publication by Physica]

The kinetic equation for a spatially uniform gas of weakly interacting point particles is used to derive the more conventional linear Fokker-Planck equation used in the description of Brownian motion. Two assumptions are required: (1) the number density of the "test" particles undergoing Brownian motion is much less than the number density of background, or "field", particles; and (2) the mass of the Brownian test particle is much greater than the mass of field particles.

11. Radiation From an Oscillating Magnetic Dipole in a Streaming Plasma*
John E. Bergeson
[Accepted for publication by Radio Science]

The electromagnetic field of an oscillating magnetic dipole is calculated, assuming that the dipole is immersed in a cold, streaming plasma. The amplitude of the magnetic dipole moment, assumed known, is taken to be sufficiently weak that the linearized cold plasma equations may be used to describe the response of the plasma.

The resulting field of the dipole is rather different from the field that would result if the plasma were not streaming. In particular, a longitudinal electrostatic field appears as a consequence of the plasma's motion. The far field of the dipole is such that the Poynting vector is not purely radical, but is tilted against the direction of the zeroth-order plasma flow.

An outward flow of mechanical energy is associated with the electrostatic field. However, the mechanical energy flow is negligible for streaming velocities small compared with the velocity of light. The force necessary to hold the dipole in place is also calculated. This force vanishes when the dipole axis is parallel to the streaming direction, as does the longitudinal electric field.

12. The Deflection of Charged Particles By a Current-Carrying Plasma*
Glenn Joyce, David Montgomery, and Celso Roque
[Accepted for publication by Physics of Fluids]

Previously derived formal expressions for the mean square deflection of a beam of energetic test particles from a spatially uniform plasma are evaluated numerically. The plasma electrons are assumed to be drifting relative to the ions with a velocity which ranges between zero and the critical drift velocity for the onset of the ion sound wave instability. Though the scattering angle diverges at the stability boundary, one must be able to make the drift velocity prohibitively close to the critical drift velocity (to within a small fraction of a percent of it) to see a marked enhancement. In no case was the scattering enhanced over the thermal value by as much as a factor of 10.

13. Inverse Third Power Law for the Shielding of Test Particles*
David Montgomery, Glenn Joyce, and Ryo Sugihara
[Work performed, in part, at Oak Ridge National Laboratory]
[Submitted to Plasma Physics]

It is shown that the effective potential of a "test charge" in a Vlasov plasma falls off, in general, as the inverse third power of the distance of the observer from the test charge, at large distances. The law applies when either (1) the test charge is in motion relative to the plasma, or (2) the plasma is anisotropic. Only when the test charge is at rest in an isotropic plasma does the exponential Debye factor appear in the effective potential.

14. Energy Exchange of Test Particles With a Plasma*
Glenn Joyce, D. J. Sigmar, K. C. Hines
[Work performed, in part, at Oak Ridge National Laboratory]
[Submitted to Physics of Fluids]

An expression for the rate of energy change of a particle moving through a Maxwellian plasma is derived starting from the Balescu-Lenard equation. This calculation is compared with calculations made in the high velocity limit and the binary collision limit.

15. Effects of Electron Temperature Variation on Ion Acoustic Waves*
I. Alexeff, W. D. Jones, and D. Montgomery
[Oak Ridge National Laboratory]
[Accepted for publication by Physics of Fluids]

It has recently been discovered how to vary the electron temperature in a simple discharge tube plasma over large ranges in a controlled manner. Subsequent use of this technique to study the propagation characteristics of ion acoustic waves in the plasma, as a function of electron temperature, has made it possible to measure properties of both the waves and the plasma: (1) the theoretically predicted dependence of wave velocity on electron temperature has been verified; (2) good agreement was found between a strong damping of the waves occurring at low electron temperatures and a theoretically predicted Landau damping; (3) an accurate means for measuring the plasma ion temperature has been found.

16. Evolution of a Nonlinear Ion Acoustic Wave*
David Montgomery
[Accepted for Publication by Physical Review Letters]

No abstract.

17. The Inhomogeneous Two-Stream Instability*
Georg Knorr
[Submitted to Physics of Fluids]

It is shown that the well known two-stream instability can under certain conditions be stabilized by the introduction of a periodic stationary electrostatic potential which is produced by the particle beams themselves.

B. IONOSPHERIC

1. Fractional Concentration of Hydorgen Ions in the Ionosphere from VLF Proton Whistler Measurements
S. D. Shawhan, D. A. Gurnett
J. Geophys. Res, *71*, 47-59, 1966.

The derivation and the accuracy of an expression relating the factional concentration of H+, $\alpha_1 = n(H) / n_e$, to the crossover frequency w_{12} for a VLF proton whistler are discussed. To an accuracy of ±3 1/2% it is found that $\alpha_1 = (264 / 255) (1 - \Lambda_{12}^2)$, where $\Lambda_{12} = w_{12} / \Omega_1$ and Ω_1 is the proton gyrofrequency. Values of α_1 have been deduced from measurement of proton whistler spectrograms for some of the satellite Injun 3 VLF data and plotted against altitude (400 - 2600 km) and against invariant latitude (20° - 63°) for summer daytime and winter nighttime of 1963. The factional concentration of H+ is found to be higher for winter nighttime than for summer daytime at all altitudes and latitudes; the ration was approximately 3:1 at 1000 km. At 1000 km the value of α_1 dropped from 0.43 in the 20° - 30° invariant latitude range to 0.27 in the 40° - 45° range for summer daytime. For winter nighttime α_1 was nearly constant at 0.82 for 1000 km from 30° to 50° latitude, but dropped to 0.75 in the 50° - 63° latitude range. Near 2400 km for summer daytime, α_1 drops from 0.65 at 46° latitude to 0.20 at 56° latitude. This same tendency is observed for winter nighttime, apparently being due to auroral-zone heating. These observations are consistent with the assumption that the heavier ions tend to predominate with increasing latitude for a given altitude. Comparison of these VLF proton whistler results for α_1 is made with reasonably good agreement to rocket ion mass spectrometer results of NASA 8.23 and to Alouette 1 VLF results deduced from lower hybrid resonance frequency. This general agreement establishes the VLF radio technique as an independent method for determining ion concentrations in the ionosphere. The general equations for uniquely determining the concentration of O+, He+, and H+ from observation of the critical frequencies (crossovers, hybrid resonances, and cutoffs) due to the presence of ions are presented, and their usage is discussed.

2. Determination of Hydrogen Ion Concentration, Electron Density, and Proton Gyrofrequency from the Dispersion of Proton Whistlers
D. A. Gurnett, S. D. Shawhan
J. Geophys. Res, 71, 741-754, 1966.

In this paper we discuss a method for determining H+ concentration, electron number density, and proton gyrofrequency in the vicinity of a satellite by measurements of the asymptotic frequency-time profile of a proton whistler near the proton gyrofrequency. This new technique is applied to proton whistlers received by the Injun 3 VLF receiver. The calculated values of H+ concentration and electron density are shown to be in good agreement with measurements by other experimenters at similar altitudes, latitudes, and local times. B values calculated from the proton gyrofrequency are compared with values calculated from the Jensen and Cain expansion for the geomagnetic field. It is shown that the wave energy of a proton whistler is guided very nearly along the geomagnetic field and that the parallel component of the group velocity is closely approximated by the group velocity for longitudinal propagation. It is found that for frequencies near the proton gyrofrequency at the satellite the kernel multiplying $n(H+)^{1/2}$ in the travel-time integral is large only in the region near the satellite. Assuming that the H+ concentration is uniform within this region, an expression is derived for the travel time of a proton whistler near the proton gyrofrequency. The H+ concentration and proton gyrofrequency are obtained by fitting this theoretical frequency-time expression to observed proton whistler signals. By combining this method for determining n(H+) with the crossover frequency method for determining $\alpha_1 = n(H+)/n_e$ the electron density can also be determined.

3. Non Eckersley Law Whistlers Observed at Equatorial Latitudes with Satellite Injun 3
G. W. Pfeiffer, D. A. Gurnett, S. D. Shawhan, and R. Shaw
Nature, 210, 827-828, 1966.

No abstract.

4. Ion Temperature in the Ionosphere Obtained from Cyclotron Damping of Proton Whistlers
D. A. Gurnett and Neil M. Brice
J. Geophys. Res., 71, 3639-3752, 1966

In this paper we discuss a method of determining ion temperature in the ionosphere from cyclotron damping of proton whistlers. These whistlers are dispersed forms of lightning impulses, observed by satellites as propagating left-hand polarized (ion cyclotron) waves. It is found that the amplitude of the proton whistler decreases abruptly at a wave frequency slightly below the proton gyrofrequency at the satellite. Of several factors considered, it is found that only cyclotron damping can satisfactorily explain this abrupt cutoff. The theory of cyclotron damping of proton whistlers is developed, and the difference between the wave frequency at cutoff and the proton gyrofrequency at the satellite is related to the proton temperature. Sample proton temperatures in the ionosphere are determined, using proton whistlers observed by the Injun 3 and Alouette 1 satellites. The temperatures found are comparable to those obtained previously by other experimenters. The method of observing ion temperatures developed here has inherent advantages in that the parameters measured are independent of electron temperature and ion composition.

5. A Satellite Study of VLF Hiss
Donald A. Gurnett
J. Geopnys. Res., 71, 5599-5615, 1966.

Broad-band VLF radio noises from about 4 kc/s to above 10 kc/s are frequently observed near the auroral zone with the Injun 3 satellite. These broad-band VLF radio noises are called VLF hiss. In this study we select VLF hiss events for analysis by requiring that the radio noise intensity from 5.5 to 8.8 kc/s exceed 3×10^{-10} $\text{gamma}^2/\text{cps}$ (about 5 times the receiver noise level). During the 10-month lifetime of Injun 3 approximately 140 events occur that satisfy this criterion. The frequency spectra of the VLF hiss observed by Injun 3 is typically a flat noise spectrum with a distincy lower frequency cutoff. The lower frequency cutoff is often found to have a nearly symmetric latitude variation centered on a region of intense electron precipitation. The range of invariant latitudes (INV) for which VLF hiss typically occurs is about 7° wide and is centered on 77° INV at 12.0 hours magnetic local time (MLT), decreasing to 72° INV at 23.0 hours MLT. On the high-latitude side of the 40-kev trapping boundary, where VLF hiss usually occurs, intense fluxes of soft electrons are often accompanied by VLF hiss. It is found that the correlation between VLF hiss and intense fluxes ($j > 2.5 \times 10^{7} (\text{cm}^{2}\ \text{ster sec})^{-1}$) of electrons ($E > 10$ kev) is dependent on the exponential folding energy E_0 from 3 to 4 kev but poor for larger E_0 values.

6. Experimental Observations of Proton Whistlers from the Injun III Data
S. D. Shawhan
J. Geophys. Res., 71, 29-46, 1966.

A new VLF phenomenon named a proton whistler has been identified in the VLF data from Alouette 1 and Injun 3 satellites. Two independent analyses on 12% of the proton whistler Injun 3 data were conducted: a semimonthly sample of data for Injun 3's 10 month lifetime to determine the gross features of proton whistlers; and a local nighttime and local daytime study of proton whistlers. Six assertions are made from these experimental observations: (1) Proton whistlers are observed only after the reception of an upward-propagating electron whistler. (2) At a frequency termed the crossover frequency (w_{12}), the initial electron whistler frequency-time trace and the proton whistler trace are coincident in time. (3) Proton whistler traces show initially a rapid rise in frequency which starts at w_{12} and which asymptotically approaches the proton gyrofrequency Ω_1 (200-650 cps for altitudes of 2700-400 km). (4) Proton whistlers occur more frequently during local nighttime than during local daytime, and they have not been observed to occur below 442 km during local nighttime of below 640 km during local daytime. (5) The ratio of the crossover frequency to the proton gyrofrequency increases with decreasing altitude and approaches unity at an altitude of approximately 440 km around local midnight and approximately 640 km around local noon. (6) There is an apparent northern hemisphere-southern hemisphere asymmetry in the occurrence of proton whistlers; they occur 3 times more frequently in the northern than in the southern hemisphere. Also, there is a high-latitude boundary in the occurrence of proton whistlers that seems to correspond with the auroral zone. The theory describing proton whistlers due to Gurnett is summarized.

7. Negative Ion Detection in the Ionosphere from Effects on
VLF Waves
Stanley D. Shawhan
J. Geophys. Res., 71, 5585-5598, 1966.

The theory for propagation of small-amplitude electromagnetic waves in a cold, homogeneous plasma including negative ions and immersed in a uniform, static magnetic field is developed. It is found that for longitudinal propagation each negative ion introduces a resonance at the negative ion cyclotron frequency, a concentration dependent cutoff frequency above the negative ion cyclotron frequency, and possibly a crossover frequency depending on the ion concentrations and charge-to-mass ratios. At both the cyclotron frequency and the cutoff frequency the group refractive index becomes infinite. Between these two frequencies there is a 'nose' frequency, for which the group refractive index is a minimum. Examples are given for a three-and five-component plasma. Application of this negative ion theory is made to propagation of negative ion whistlers in the ionosphere. It is found that for frequencies near the negative ion cyclotron frequencies the WKB approximation is valid above 300 km during the nighttime and 150 km during the daytime. Effects of collisions can be neglected above 150 km. An ideal experiment is proposed for observation of negative ion whistlers (1-1000 cps). Sample whistler, frequency-time spectrograms like those that would be observed with such an experiment are sketched. From the distinctive frequencies on these sample spectrograms, it is shown that the negative ion specie and concentration can be determined using the developed cold plasma expressions.

8. Satellite Observations of VLF Emissions and Their Associaton with Energetic Charged Particles*
Donald A. Gurnett
Paper presented at the NATO Advances Study Institute on EARTH'S PARTICLES AND FIELDS, July 31 - August 11, 1967
Freising, Germany, [To be published in the Proceedings of this meeting, 1968].

A summary of recent satellite observations of VLF emmissions and their association with energetic charged particles is presented. Using data from the Injun 3 satellite maps of the broadband intensity of magnetospheric VLF emissions are shown as a function of invariant latitude and magnetic local time. Examples of the simultaneous occurrence of VLF emissions and energetic charged particle precipitation are discussed.

9. Microburst Phenomena 3. An Association between Microbursts and VLF Chorus*
N. M. Oliven and D. A. Gurnett
[Accepted for Publication, J. Geophys. Res., 1968].

Observations made with the Injun 3 satellite of bursts of precipitating $E_e \geq 40$ keV electrons and of VLF chorus emission have revealed their simultaneous occurrence. Observed microbursts are always accompanied by a group of VLF chorus emissions; chorus is not necessarily accompanied by microbursts. The maximum region of microburst occurrence from $0400 \leq$ magnetic local time ≤ 1300 and $65^\circ \leq$ invariant latitude $\leq 70^\circ$ lies well within the maximum region of chorus emissions from $0300 \leq$ magnetic local time ≤ 1500 and $55^\circ \leq$ invariant latitude $\leq 75^\circ$. It is not generally possible to find a one to one (burst to burst) correspondence between individual microbursts and VLF chorus bursts.