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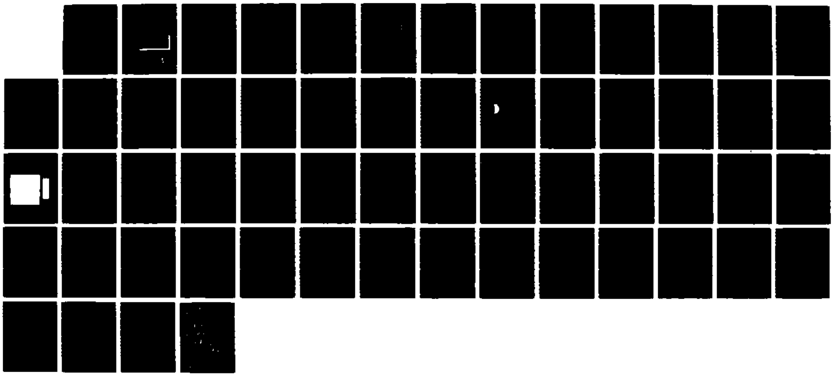

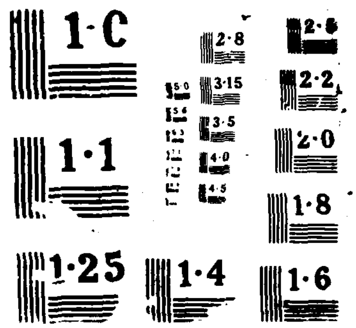
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CENTER FOR SPACE RESEARCH

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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This annual report contains a detailed description of the activities, accomplishments, and research progress of the Center for Theoretical Geoplasma Physics at MIT established under the AFOSR-URI program during the first year of its operation. Much has been accomplished during the past twelve months. Research topics considered by the members of the Center include: ionosphere-magnetosphere coupling, high-latitude ionospheric turbulence, charged particle acceleration and heating, nonclassical polar wind, double layers, magnetic reconnection, strong MHD turbulence, plasma radiations induced by moving conducting objects in the low-altitude ionosphere, and F-region sub-visual polar arcs. The Center has interacted actively with scientists from many research and academic institutions around the globe including strong links with Dr. J.R. Jasperse, Dr. H. Carlson and other members at the Air Force Geophysics Laboratory. This is accomplished through an extensive visiting scientist program at the Center and by visits of the members of the Center to the various institutions. Workshops, symposia and seminars have been organized throughout the year.

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Proceedings in book form have been published to document these collaborative research and educational activities. During the year, members of the Center have contributed twelve scientific articles and presented numerous invited lectures and scientific papers at various national/international conferences and academic/research institutions and laboratories. A highlight of the year was the visit by Professor Hannes Alfven, Nobel Laureate in Space Plasma Physics, who discussed current research topics with the members of the Center, delivered an opening address at the MIT Symposium on the "Physics of Space Plasmas", and contributed a lead article in volume six (6) of the proceedings series of the same title.

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Reported by: Tom Chang, Director

ANNUAL TECHNICAL REPORT

Number One

FOR CONTRACT NUMBER F49620-86-C-0128

Covering the Period

From October 1, 1986 to September 30, 1987

(*Program Manager: James P. Koermer, Lt. Col, USAF*)

CENTER FOR
THEORETICAL GEOPLASMA PHYSICS

Center for Space Research

Massachusetts Institute of Technology

(an AFOSR URI program)

Reported by Tom Chang, Director

Cambridge, Massachusetts

November 15, 1987

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II. PROLOGUE

During the past year, the Center for Theoretical Geoplasma Physics at MIT has made definite strides toward the goals prescribed in its original AFOSR-URI proposal.

We have initiated a number of new research activities while continuing some of our previous research programs which are of relevance to the theme of the research center. These include the study of the nonclassical polar wind, the application of magnetohydrodynamic turbulence to the phenomenon of ionosphere-magnetosphere coupling, the analytical description of double layers along auroral field lines using nonlinear plasma stability theories, the origin of high-latitude ionospheric turbulence and its relevance to charged particle acceleration processes, and the investigation of the inter-relations of the particle precipitation, plasma waves, field-aligned currents, convection patterns, the direction of 'he inter-planetary magnetic field, and the mysterious sub-visual polar cap arcs.

The Center has interacted actively with a number of research organizations including the Air Force Geophysics Laboratory, the Southwest Research Institute, the Lockheed Palo Alto Scientific Research Laboratory, The Swedish Space Institute, the Finish Meteorological Institute, the Max-Planck Institute for Extraterrestrial Physics, Cornell University, the University of California at Berkeley, the University of California at Irvine, the Imperial College, the University of Maryland, and the Taiwan Center for Space and Remote-Sensing Research. Visits by scientists from these institutions and our visits to some of these institutions helped to keep our research program vibrant and up-to-date. In particular, Dr. J.R. Jasperse of the Air Force Geophysics Laboratory has provided the guidance and inspiration of our entire technical program.

Our computer capability has been greatly enhanced. Through our network of Sun workstations, we are now tied to the MIT ethernet, and nearly all the networks worldwide. We continue to have access to the Cyber machine at the Air Force Geophysics Laboratory and have a fast speed access (56 kbps) to the von Neumann Supercomputer Center at Princeton, N.J. Dr. G.B. Crew is the coordinator for these computing activities at the Center.

The Center is fully staffed with fifteen (15) active members. These include members of the faculty, staff, postdoctoral and graduate students from MIT and several visiting scientists from other interacting institutions.

The Center organized an annual symposium on the "Physics of Space Plasma" which included a leadoff lecture on the "Plasma Universe" by the Nobel Laureate, Professor Hannes Alfven of the Swedish Royal Institute of Technology. Over one hundred and fifty scientists (150) participated including many from the Air Force Geophysics Laboratory. The Center also jointly sponsored with the Air Force Geophysics Laboratory the First Cambridge Workshop in Theoretical Geoplasma Physics on the subject, "Ionosphere-Magnetosphere-Solar Wind Coupling Processes." The workshop attracted over one hundred and thirty (130) international participants including over thirty (30) graduate students. A proceedings volume based on the symposia on the Physics of Space Plasmas was just published by the Scientific Publishers. Another volume on Ion Acceleration was published by the American Geophysical Union as Volume 38 of its renowned Geophysical Monographs Series.

Members of the Center have been invited by various conferences, universities and other organizations to deliver invited and review lectures. During a short period of less than twelve months, the Center has produced a dozen technical papers, some are already in print while others have been accepted or submitted for publication. Members of the Center presented numerous technical papers at various national and international conferences.

The organization of this annual report is as follows:
Detailed descriptions of the research progress and important accomplishments are given in Section III. Lists of technical papers, conference presentations and invited/review lectures are given in Sections IV to VI. Names of the professional personnel associated with the Center are listed in Section VII. Sections VIII and IX detail the names of the scientists who visited our Center and the the extent of their interactions with the research and academic staff of the Center. Lists of symposia and workshops as well as published proceedings are given in Sections X and XI. Penultimately, an outline of the Center's computer capabilities is provided in Section XII. Finally, a short summary appears as Sections XIII.

III. RESEARCH PROGRESS AND ACCOMPLISHMENTS

III.1 TRANSVERSE ACCELERATION AND HEATING OF IONOSPHERIC IONS AND THE FORMATION OF ION CONICS

Geoplasma physicists have measured positively charged ionospheric ions at the auroral and polar cusp latitudes. These ions appear to gyrate around the geomagnetic field lines at extremely high speeds while flowing upward from the low altitude ionosphere into the magnetosphere with energies ranging from tens of eV to tens of keV; and populations of these ion distributions have been christened "ion conics". The name "conic" refers to the fact that these ion distributions are strongly peaked in pitch angle, so that they are concentrated on a cone in velocity space. The discovery of conics was somewhat startling, largely because no mechanism for transversely accelerating ionospheric ions to what are essentially magnetospheric energies had been anticipated. The ions were probably accelerated transversely by the plasma waves that are omnipresent in the turbulent region of the high latitude ionosphere and magnetosphere. Because the geomagnetic field decreases with altitude, as the ions will drift to higher altitudes, some of this transverse energy is converted to upwards motion, thereby transforming the distributions into conics in velocity space.

We have contributed some very important theoretical discoveries pertaining to the basic heating mechanisms of this type of ion population and made some definitive strides towards the prediction and calculation of the details of the various types of ion conic distributions in the geoplasma environment. We have been invited by various international conferences and research institutions to lecture on these ideas, culminating in a review lecture given at the Third International School on Space Simulations at Beaulieu, France in June 1987 and an invited lecture at the Twenty Second General Assembly of the International Union of Radio Science in Tel Aviv, Israel in September 1987. Some of these new research results are summarized in the following three sub-sections.

III.1.a TRANSVERSE HEATING OF IONOSPHERIC IONS ALONG AURORAL FIELD LINES BY INTENSE ELECTROMAGNETIC TURBULENCE IN THE ION CYCLOTRON RANGE OF FREQUENCIES

As discussed above, ion conics have been observed in various regions of the Earth's ionosphere-magnetosphere system and is a current research topic of intense theoretical interest. We have made considerable progress in explaining a class of these events through a theory in which the energization of the conics arises through cyclotron resonance with a broad band of electromagnetic waves that are frequently observed in the turbulent region of the high-latitude ionosphere. The nature of this acceleration mechanism is such that it has been possible to make significant analytic progress towards a description of the resulting particle distributions.

We have performed a series of Monte Carlo particle simulations to test the ideas of our theory and to make quantitative comparisons with the observed particle distributions. At each altitude one can approximate the effects on the particle distribution through local cyclotron resonance with the observed low frequency turbulence by means of a quasilinear-type velocity space diffusion operator. Since the waves are present over a range of frequencies corresponding to cyclotron frequencies over a range of altitudes in the Earth's bipolar magnetic field, the ions are able to extract energy continuously as they drift up along the geomagnetic field lines. With reasonable assumptions, the Monte Carlo simulation is able to quantitatively trace the evolution of the entire distribution of particles throughout this process, and *the agreement with the conics observed in the central plasma sheet by the Dynamics Explorer 1 satellite is dramatic*

*(Fig. 1). To our knowledge, this represents the first quantitative comparison between **any** theory of ion acceleration with ion populations observed in space. Our results were recently reported in the prestigious journal, Physical Review Letters (59, 148, 1987).*

Encouraged by these results, we have pressed our theoretical analysis of this mechanism with a number of goals in mind. These include an enhanced understanding of the process, a sharpening of theoretical tools for their potential application to other problems, and a recognition that while numerical simulations are useful for demonstrating the validity of theoretical notions, they are sorely inadequate for application to the analysis and reduction of sizable data sets. For example, we have identified a scaling which may be used to advantage in reducing the dimensionality of the problem and have reformulated the reduced problem in terms of a Langevin equation. One result of this reformulation is an improved numerical simulation which achieves results similar to the Monte Carlo simulation with an increased efficiency that translates into a reduction of the computer time required by orders of magnitude.

Of equal significance is the fact that this reformulation makes a natural starting point for further theoretical development. In particular, exploiting techniques originally developed in condensed matter and elementary particle physics, we are effectively able to obtain a closed form solution of this quasilinear diffusion problem in terms of a path integral similar to those employed in quantum field theory. Furthermore, the result is amenable to evaluation by Feynmann diagrams in order to calculate the various moments of the conic distributions, for example, particle and energy fluxes.

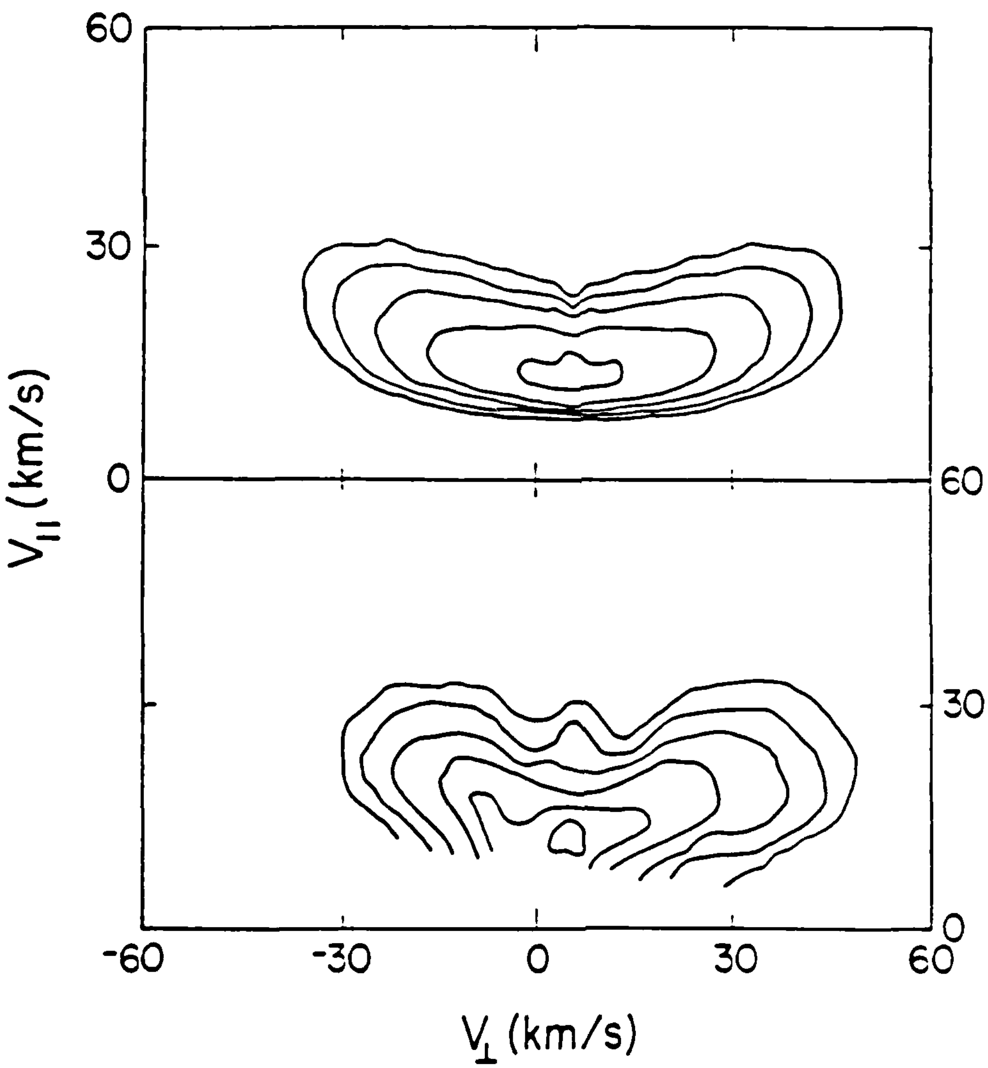
Armed with these theoretical tools we are now in a favorable position to attack the existing data set of ion conic events. In particular, with the right tools, it should be possible to extract considerably more information concurring the physics of these ionosphere events and their relations to the global problems. We have begun such a combined theoretical/experimental investigation with investigators of the particle and wave experiments on the Dynamics Explorer 1 satellite.

We have also been collaborating with our visitor from Sweden, Dr. Mats Andre of the Viking Polar-Orbiting Satellite Science Team. Viking has often observed perpendicular heating of ionospheric ions both in the auroral region and in the polar cusp, and for most of these events, electric and magnetic wave data are available. Our study concentrated on some of the interesting events in the cusp where Viking observed locally heated ions (mostly in the polar cusp region.) Here the plasma waves observed by the spacecraft should be those actually responsible for the heating. We found that the plasma waves have a significant left-hand polarized component which should be efficient for cyclotron resonance heating of positively charged ionospheric ions. By using the observed wave amplitudes and polarization consistent with the observed data, we discovered that the electromagnetic ion cyclotron resonance mechanism can be employed to explain the observed ion data. Preliminary Monte Carlo calculations gave very encouraging results in the detailed description of these ion distributions. The method of calculation is similar to that employed for the central plasma sheet ions. However, since the wave intensity here is extremely intense and may occur over several thousand kilometers along the cusp field lines while the ions are heated in a rather narrow range of altitude as they drift poleward due to the presence of a large convection magnetic field, the detailed calculational procedure is somewhat different.

As mentioned above, these Viking events were detected in the cleft/cusp region of the ionosphere/magnetosphere. *This makes our study even more interesting since the cleft region is known to be an important source of ionospheric ions entering the magnetosphere and yet no detailed discussion of the ion heating mechanism has been given previously by the geoplasma physicists for this region.*

In addition to Dr. Andre, we have benefited by many useful interactions with and collaborative research efforts of Dr. J. R. Jasperse of the Air Force Geophysics Laboratory, Dr. J. M. Retterer of the Space Data Analysis Laboratory of the Boston College, Dr. J. D. Winningham of the Southwest Research Institute, Drs. W. Peterson, D. M. Klumpar and E. Shelley of the Lockheed Palo Alto Research Laboratory, Drs. R. Huff, M. Mellott and D. Gurnett of the University of Iowa, Dr. N. Hershkowitz of the University of Wisconsin, Dr. H. Koskinen of the Finish Meteorological Institute and Dr. R. Erlandson of the Applied Physics Laboratory, Johns Hopkins University.

Fig. 1 The bottom panel presents a contour diagram of the observed oxygen-dominated ion conic distribution function in the central plasma sheet, measured by the HAPI instrument on Dynamics Explorer 1 on Nov. 14, 1981 at the geocentric altitude of $2.0R_E$ and invariant latitude of 60°. The top panel presents the theoretical contours for the same event based on the Monte Carlo simulation calculation. The contours are uniformly spaced with an increment of 0.4 in the logarithm of phase space density. The density of these ions at the observation point is approximately $10 cm^{-3}$.



III.1.b ACCELERATION OF IONOSPHERIC IONS BY LOWER HYBRID WAVES IN THE BOUNDARY PLASMA SHEET

During a magnetic substorm, the plasma sheet thins down and numerous plasma processes are induced. For example, in the boundary layer region of the plasma sheet at altitudes around 1 Re, strings of weak double layers have been detected along the geomagnetic field lines (Figs. 2 and 3). These double layers characteristically have potential drops of the order of 1 eV over a spatial extent of several Debye lengths and are generally observed to propagate upward along the field lines. These double layers seem to set in intermittently in space and in time, and on the average are separated along the magnetic field lines at approximately 1 km intervals. They are probably produced by some sort of current driven nonlinear plasma instability (which will be discussed in Section III.2a in this report). It can be argued that during a magnetic substorm, upward field-aligned currents are the strongest at altitudes around one earth radius in the boundary plasma sheet region. Such a region can have an altitudinal extent of over 1000 km. Thus, on the average, electron populations can be accelerated by the combined effect of these potential drops to above 1 keV. Indeed, keV electron beams have been detected streaming toward the ionosphere in the boundary plasma sheet. In addition to creating the visibly observable discrete aurorae in the E-region of the ionosphere, such electron beams can also excite a number of plasma instabilities in the supraauroral region. In particular, in situ observations have detected enhanced wave intensities near and above the lower hybrid resonance frequency.

In addition to the observed lower hybrid waves, simultaneous in situ measurements have also detected *counterstreaming electron populations and ion conic distributions* such as those described above. Above the kilovolt potential drops, on the other hand, upflowing keV ion beams have been detected along with enhanced emissions of electrostatic ion cyclotron modes.

In Sec. III.1.c, we will discuss our work on the generation of the lower hybrid turbulence in the high latitude ionosphere and local nonlinear ion heating using two-dimensional particle-in-cell plasma simulation techniques. The evolution of the ion population, however, is a mesoscale problem: energy input to the ions is continuous over a range of altitudes along an auroral flux tube. Thus, analytic and Monte Carlo simulation techniques are much more appropriate. *Using diagnostics of the plasma simulation, one may obtain detailed information about the wavenumber spectrum of the turbulence which is normally not observable, and from this construct a velocity-space diffusion operator to describe the wave-particle interactions.* One may then introduce this heating term into the Vlasov equation in order to obtain an evolution equation for the conic distribution function.

Typically the phase velocity of the lower hybrid waves is much greater than the thermal velocity of the ion distribution and this may be used to advantage to construct analytic solutions of this evolution equation. Specifically, this ratio is a small parameter that may be used to obtain asymptotically correct solutions to the heating portion of the equation. The effects of the magnetic mirror force and a possible field-aligned potential may then be added by means of an adiabatic transformation of the heated distribution. (See Fig. 4).

These results may be compared and contrasted with the numerical treatment of the Monte Carlo simulation which simultaneously models both the heating and convective effects accurately. The comparison shows that the analytic solutions are in fact quantitatively useful far beyond their formal domain of validity, at least as far as the moments of the distribution are concerned. The major discrepancy is that the analytic treatment tends to make conics that are narrow in pitch angle. This is due to the neglect of what amounts to pitch angle scattering of the distribution as it evolves up the flux tube under the effects of the mirror force. The energy distribution of the conic is rather well approximated, however.

This work has been performed in collaboration with Dr. John M. Retterer of Space Data Analysis Laboratory of the Boston College and Dr. John R. Jasperse of the Air Force Geophysics Laboratory.

Fig. 2 Plasma Sheet Regions

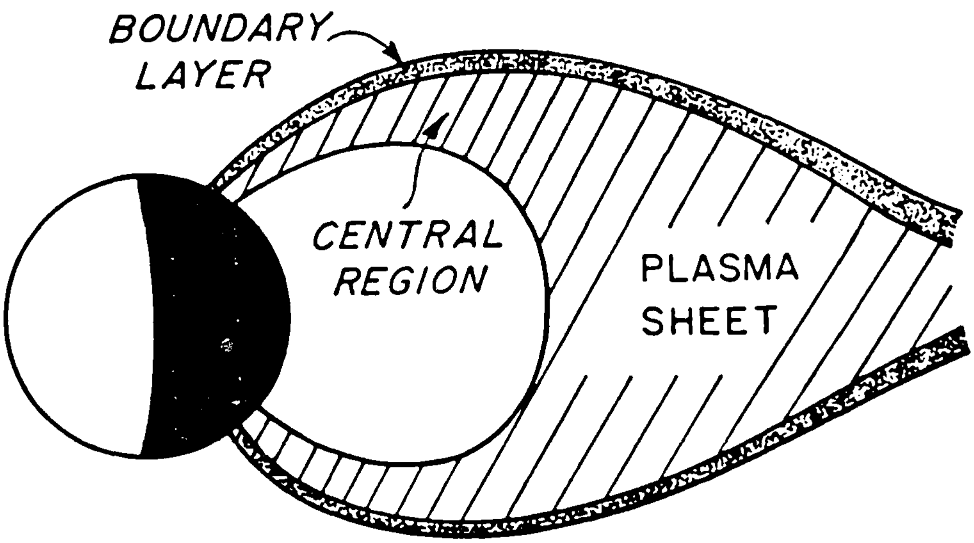


Fig. 3 **Boundary plasma sheet (BPS) field line**: (a) Region where weak double layers have been detected. (b) Region where lower hybrid waves, ion conics, and counterstreaming electrons have been detected. (c) Region where ion beams and electrostatic ion cyclotron waves have been detected. **Central plasma sheet (CPS) field line**: (d) Region where low frequency electromagnetic waves in the ion cyclotron range of frequencies and oxygen-dominated, shallow conics are detected.)

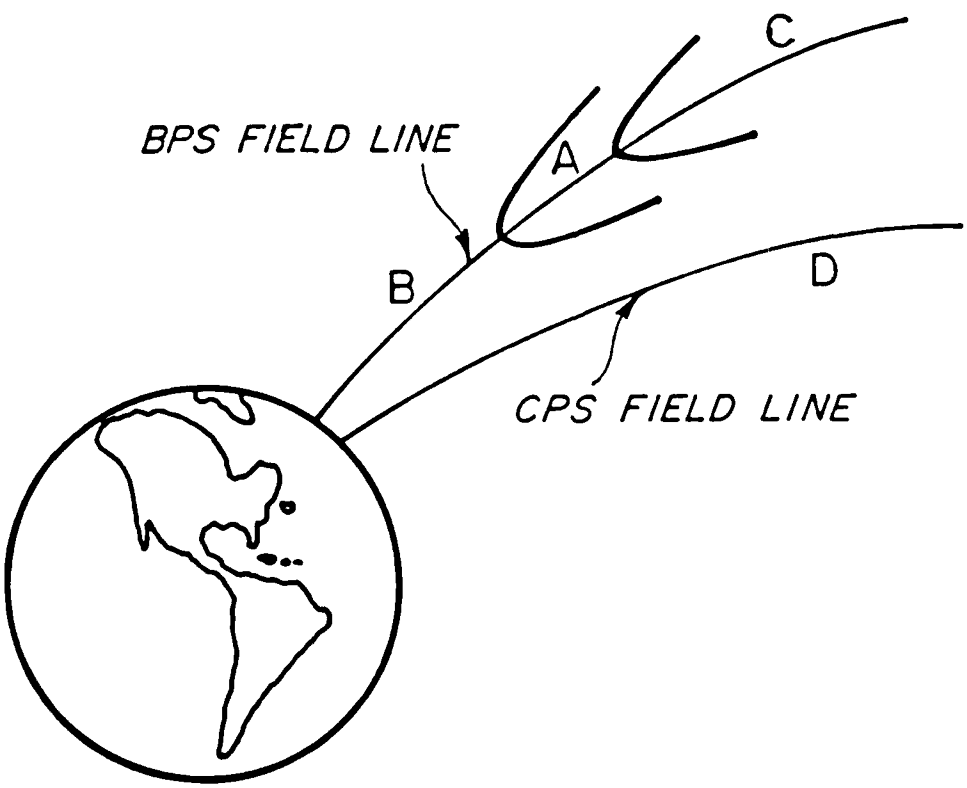
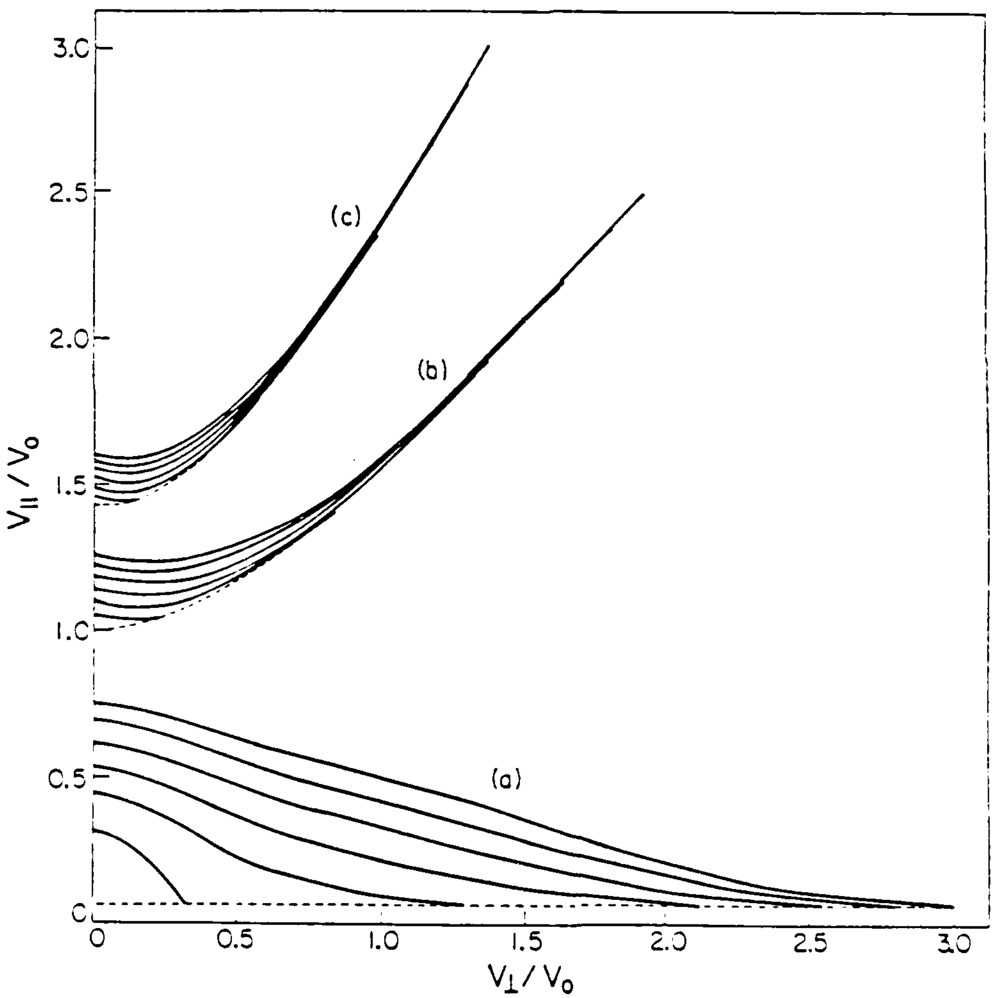


Fig. 4 Evolution of an hydrogen ion conic based on the analytical solution using the two-stage approximation. The diffusion layer is 10km thick. Typical ionospheric conditions are assumed and the root mean square electric field intensity E_w=33mV/m. Cases (a), (b), and (c) are at altitudes 10, 2500, and 5000 km above the base of the diffusion layer.



III.1.c TWO-DIMENSIONAL PARTICLE-IN-CELL PLASMA SIMULATION OF HIGH-LATITUDE LOWER HYBRID TURBULENCE AND CHARGED PARTICLE ACCELERATION

Wave-particle interaction with the intense VLF hiss observed below auroral arcs is an attractive mechanism for the transverse acceleration of ions into energetic ion conics and the particle acceleration of electrons into the counterstreaming velocity distributions occasionally seen with ion conics. Although one-dimensional simulations have demonstrated that this mechanism can be effective for particle acceleration, a number of interesting phenomena can be realized only in higher dimensions. For example, the convective linear growth rates and dispersion of VLF waves on the whistler resonance cone depend crucially on the angle of propagation with respect to the magnetic field, but one-dimensional simulations can study only a single propagation angle at a time. Mode-coupling processes cannot be studied in complete generality in one-dimension either, because wave vectors are constrained to be aligned in the same direction.

We have performed two-dimensional particle-in-cell plasma simulations to study the ion and electron acceleration by VLF turbulence in the auroral region. We found strong particle acceleration, both of the electrons and of ions. Because of the restricted perpendicular mobility, electron acceleration occurs primarily parallel to the magnetic field. The acceleration causes energetic tail formation on the electron parallel-velocity distribution, both in the direction of the beam and in the opposite direction, (i.e. *counterstreaming electrons*). This unique acceleration phenomenon of the electrons can be attributed to resonant interaction with the short-wavelength waves excited by the nonlinear decay of the long-wavelength waves linearly excited by the primary auroral electron beam.

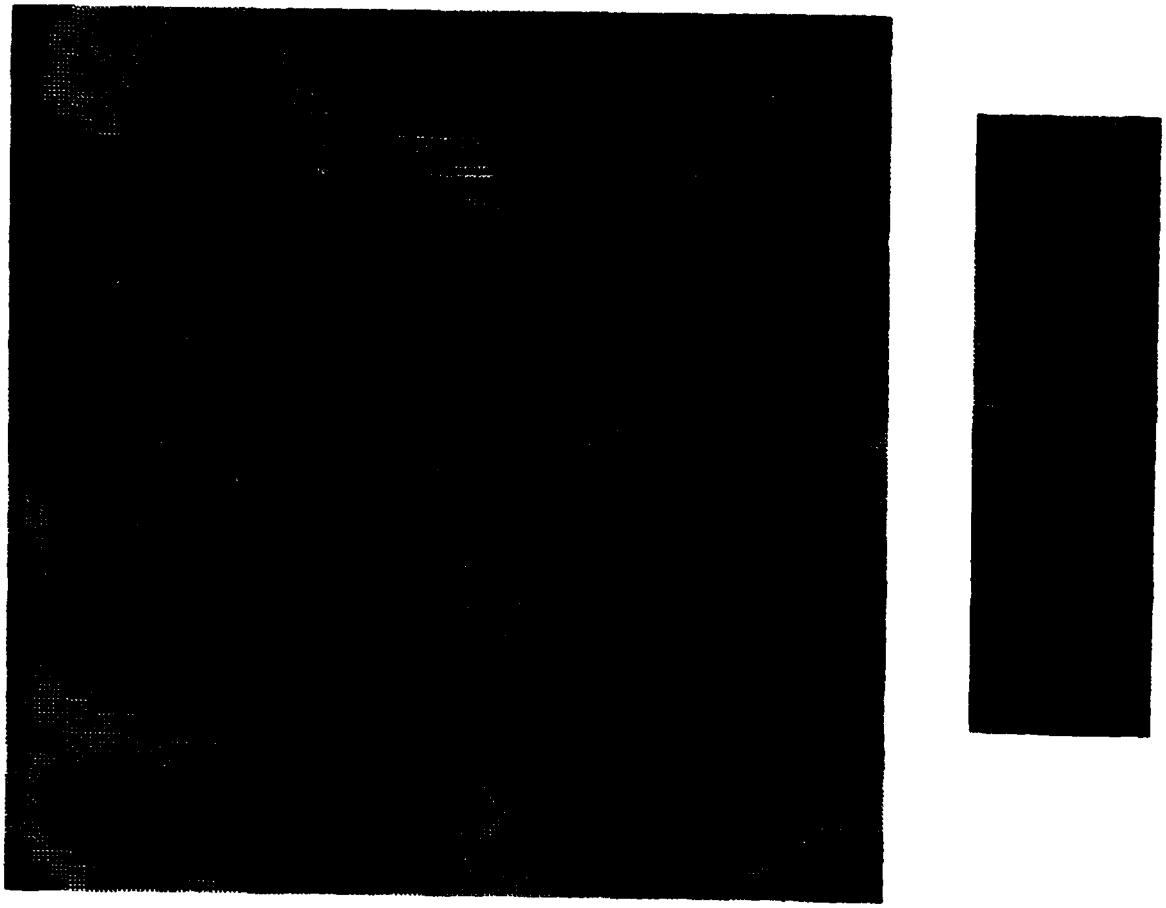
The ions, on the other hand, tend to be accelerated in the direction perpendicular to the magnetic field and lighter ions are accelerated to greater individual energies than heavier ions. These are both consequences of the resonant nature of the interaction with the waves: the perpendicularly propagating waves have lower frequencies and phase velocities, so the ions can more easily interact with them, and lighter ions have higher thermal velocities and will be more likely to match the phase velocity of a wave. Given the observed wave spectrum, the quasilinear description of particle acceleration appears to be adequate to account for both the electron and ion acceleration observed.

Much of the interesting physics of the simulation is contained in the evolution of the waves. It was found that the waves are generated at relatively long wavelengths by the linear instability. Once these waves become intense enough, they succumb to a variety of nonlinear mode-coupling processes which attempt to thermalize and isotropize the spectrum (Fig. 5). The mode-coupling processes aid particle acceleration by making the excited waves more accessible in phase velocity to the low energy ions and electrons. We found the cascading process of nonlinear mode-coupling in the lower hybrid range of frequencies is governed by a coupled set of nonlinear Schroedinger equations. The complete turbulent wave-particle interaction picture is then obtained by adding dissipation to the equations.

We have compared our analytical results to experimental observations. *In particular, a recent rocket campaign over Greenland, code named MARIE,* *has provided us with what is probably the most complete and detailed set of observation in the ionosphere within the low-altitude transversely accelerated ions available*. Our simulations provide a model for the processes occurring during the formation of ion conics near auroral arcs, as reported in these observations. From the in-situ plasma and wave measurements, a strong correlation is found between VLF wave intensity and energetic ion flux; preferential acceleration of hydrogen over oxygen occurs; and enhancements of field-aligned electron fluxes are found. The frequency spectrum of the VLF turbulence around the lower hybrid frequency shows structure spaced at the hydrogen gyrofrequency, suggesting that ion damping of the waves is responsible for the acceleration; the amplitude of the VLF turbulence is several tens of mV/m, strong enough to account for the ion energies. Finally, the form of the ion velocity distribution has the high energy tails that are characteristic of the acceleration observed in the simulation. In addition, there are provocative new observations of intense VLF wave packets observed in conjunction with the transversely accelerated ions.

These exciting results involving high-latitude strong ionospheric turbulence are conducted with the enthusiastic interactions of our colleagues: Dr. Andrew Yau from the National Research Council in Canada, and Professor Paul Kintner of Cornell University, Dr. J. M. Retterer of the Space Data Analysis Laboratory of the Boston College, and Dr. J. R. Jasperse of the Air Force Geophysics Laboratory. We have reported some of these research findings at the Third International School for Space Simulation at Beaulieu, France in June 1987.

Fig. 5 Snapshot of the electrostatic potential in the plane of a two-dimensional simulation of the lower hybrid instability. Striations in the horizontal direction result from linearly excited waves, while in the vertical direction show a nonlinearly excited wave.



III.2 IONOSPHERE-MAGNETOSPHERE-SOLAR WIND COUPLING PROCESSES

III.2a AURORAL DOUBLE LAYERS

Double layer potential structures in the boundary plasma sheet have been suggested as the dominant field-aligned, particle acceleration mechanism for auroral electrons and upflowing ion beams. The conventional explanation for the development of these double layers is the evolution from linearly unstable ion acoustic modes into ion holes. However, the observed ratio of auroral electron to ion temperatures and electron drift speed seem to be more consistent with stability rather than instability of ion acoustic waves.

It is paramount for the space plasma physicist to have a definitive understanding of the generation and evolution processes of the auroral double layers because it is central to the basic knowledge of ionosphere-magnetosphere coupling and high-latitude ionospheric turbulence. We have recently proposed a new mechanism for the onset of auroral double layers in terms of a nonlinear ion hole instability. The unique feature of this instability is that it can occur even in linearly stable plasmas. The holes develop intermittently in phase space and, in such relative isolation, can grow in a current-carrying plasma with any temperature ratio and electron drift speed. We have compared the results of our ion hole-double layer structure with the observed satellite data, particularly those obtained from the S3-3 and VIKING spacecrafts. We found favorable quantitative agreement for the critical drift speed for ion hole growth, as well as for the characteristic speed, spatial size, depth, and potential structure of these double layers.

These results are most satisfying in three respects:

1. Our theory resolves the outstanding puzzle of the observation of nonlinear potential structures of double layers in a linearly stable current-carrying auroral plasma.

2. Our theory is the first bonafide, nonlinear, renormalized plasma theory which produces a nonlinear instability yielding accurate predictions about an important aspect of the ionosphere-magnetosphere coupling process along auroral field lines.

3. Our theory agrees with a carefully conducted large scale, numerical plasma simulation which demonstrates unequivocally that a linearly drifting plasma can become nonlinearly unstable and produce ion-hole double-layer like potential structures.

We have presented these results at the 1987 Cambridge Workshop on Ionosphere-Magnetosphere-Solar Wind Coupling Processes and also submitted a manuscript for publication in the Geophysical Research Letters.

In the course of this research, we have interacted with research scientists from the S3-3 and VIKING team, particularly Dr. M. Temerin from the University of California at Berkeley and Dr. H. Koskinen from the Finish Meteorological Institute.

III.2b MHD CLUMP INSTABILITY AND TURBULENT MHD STEADY STATE RECONNECTION

One of the most fundamental plasma problems in the physics of ionosphere-magnetosphere-solar wind coupling is the process of magnetic reconnection on the dayside magnetopause region and in the magnetotail. It is generally believed that the resolution of this complex phenomenon can give some definitive hints to the dynamo problem which has plagued the space geoplasma physicists for several decades. Nearly all existing theoretical studies of magnetic reconnection are based on linear instability ideas near magnetic null points followed by nonlinear evolution calculations. On the other hand, data near the dayslide magnetopause and in the magnetotail seem to strongly indicate turbulent reconnection processes in the presence of magnetic shear. Clearly an entirely different avenue of approach to this difficult problem is needed.

Recently, we have developed a MHD clump instability theory which is a bonafide nonlinear magnetohydrodynamic turbulence theory in the presence of magnetic shear. Nonlinear instability results when, as the clump magnetic island structures resonantly overlap, the mixing overcomes clump decay due to magnetic field line stochasticity. The instability growth time is on the order of the so called Lyapunov time. The renormalized dynamical equation describing the MHD equations can conserve the dynamical invariants of the exact equations. This instability is a nonlinear analogue of the Raleigh-Taylor instability in a magnetized fluid and, in the fluid stochastic case, of the tearing mode instability.

We have also studied the turbulent steady state of this instability. We discovered that the concept of magnetic helicity conservation plays a decisive role in the steady state and that the process of turbulent magnetic reconnection is a bonafide three-dimensional problem. The steady state is determined by the balance between the helicity conserving growth by turbulent mixing and clump decay by field line stochasticity. The self-consistent generation of fields during MHD clump instability is the type of turbulent dynamo action that space physicists are looking for. We are applying these ideas to the magnetic reconnection phenomenon in space as well as those recently simulated in the laboratory. In addition, we are discovering that these renormalized nonlinear MHD concepts are also applicable to the intriguing problem of strong trubulence cascade in the high-latitude region of the ionosphere.

III.3 STUDY OF DETAILED PARTICLE DISTRIBUTION AND PITCH ANGLE SCATTERING IN THE DIFFUSE AURORA

The most common description of the scattering process involving the electron population in the diffuse aurora assumes that the scattering is always strong enough to maintain an isotropic pitch-angle distribution. However, satellite observations (ISIS-2 and DE1) have shown unequivocally that the pitch-angle distributions of the electrons generally have partially filled loss-cone distributions.

We have produced a detailed kinetic model of plasma sheet convection, precipitation, and backscatter. The trapped particle velocity distributions are described by a numerical solution of the bounce-averaged diffusion equation including the advective terms necessary to describe the effects of convection. The precipitating flux is determined by a boundary-layer treatment of the loss-cone in velocity space, while its interaction with the atmosphere is modeled using a numerical transport code. The description of the pitch angle distribution and its variation along the geomagnetic field line is obtained by matching asymptotically the boundary layer solution of the pitch angle diffusion equation to that of the outside of the loss cone, which can be obtained using a bounce-averaged diffusion equation.

The output of the model includes the pitch-angle and energy distributions of the particles as functions of latitude both in the trapped distribution and at low altitude. When the pitch-angle diffusion rate falls with energy, the precipitative loss rate peaks near the energy marking the transition to the strong-diffusion limit. The kinetic model demonstrates that this nonuniform loss rate can produce shell-like electron distribution functions, whose non-Maxwellian nature can be another means by which the upper hybrid and electron cyclotron harmonic waves observed within the equatorward of the auroral zone can be excited.

This research was carried out in close collaboration with the visiting scientists of our Center, Dr. J.M. Retterer of the Boston College and Dr. J. R. Jasperse of the Air Force Geohysics Laboratory.

III.4 A NEW NONCLASSICAL POLAR WIND THEORY

Ion measurements in the polar wind collected by the Dynamics Explorer 1 satellite have noted conic distributions whose energy and shape differ drastically from the type of ion distributions suggested by the classical polar wind theory. In addition, VLF waves and low frequency electromagnetic noise were also detected in this region. This is very puzzling since there are no appreciable currents in the polar wind to excite these waves. At the same time, the observed photoelectron distributions along open field lines over the polar cap appeared to be quite anomalous. These electrons generally acquire a cigar-shaped pitch-angle distribution which is asymmetric with respect to the upgoing and downcoming directions. It appears to carry very little current but a large amount of outward heat flux.

We have initiated a unique calculation to describe the behavior of such type of polar wind photoelectrons. Realizing that the electrons in question are produced by photoionization processes through solar uv spectrum and have experienced various types of collisions in the lower ionosphere before escaping to higher altitudes, we constructed a globally collisional model using the various, relevant collisional operators and realistic collision cross-sections. The global equation is then solved using the Monte Carlo technique. Although the calculations are still in the initial stage of development, we believe that the nature of the formulation will yield photoelectron distributions of the forms that are comparable to the observed results. Such photoelectron distributions do not carry any current but will carry a large outward heat flux, and they should be unstable to low frequency and VLF waves. A self-consistent field-aligned electric field is also expected to emerge automatically from the self-consistent calculation. The existence of field-aligned electric fields along polar cap open field lines is an observational fact from ISIS-2 and Dynamics Explorer 1 satellites. The excited low frequency and VLF waves should be able to accelerate the ions to the type of nonclassical ion conic distributions as observed.

We have benefited from very useful discussions with Dr. J.D. Winningham from the Southwest Research Institute who performed the pioneering work on the nonclassical polar wind via instruments aboard both the ISIS-2 and DE1 satellites.

III.5 PLASMAS RADIATIONS IN THE LOW-ALTITUDE IONOSPHERE DUE TO MOVING CONDUCTING OBJECTS

There are many situations of interest in the Earth's ionosphere which consist of a conducting body moving through a magnetized plasma medium. Large conducting space structures in low earth orbit will have a nonnegligible motionally induced potential across their structures. The induced current flow through the body and the ionosphere generates plasma radiations of Alfven and lower hybrid waves. This phenomenon of plasma wave radiation due to the motion of a spacecraft in a magnetized ionosphere is of extreme importance to large systems such as the long antenna booms on a scientific satellite for measuring low frequency electromagnetic waves in the ionospheric medium (or the long conducting tether of a tethered satellite) and the space station.

Since the current source is moving, in a fixed frame, the current will appear to be AC. The problem of radiation from induced AC currents into the surrounding plasma is of interest for two reasons. Firstly, for large space structures such as the long antenna booms on a scientific satellite or the space station, there may be inductive coupling between the power distribution system and the motionally induced current flowing through the structure. Secondly, for large structures such as the electrodynamic tether, one potential use is as a broadcasting antenna to communicate information to the surface of the earth. The major difference between these two cases is that in the former the system is passive, that is the current flow in the structure is due only to the induced potential while in the latter the system is active, i.e., current is actively driven through the tether. For passive systems it is desirable that the radiated power be as small as possible since it represents a loss of power from the structure. Also, for the wave-measuring antennae, the radiations may inject spurious signals into the desired measurements. For an active system like a broadcasting antenna, the radiated power should be as large as possible so as to achieve a high signal to noise ratio.

We have developed a general formalism which permits us to compute the response of the ionospheric plasma to an external current source. We derived an integral equation which relates the source current to the electrical properties of the conducting body. This formalism enables us to estimate the total radiated power for moving conductors. We find that in general the radiation is produced at all frequencies for which one of the plasma modes has zero phase velocity in some direction. The mechanism by which this radiation is produced is analogous to Cherenkov radiation. In the cold plasma approximation, there are generally radiations into three frequency bands. Important scaling laws are derived for plasma radiations in the MHD and lower hybrid frequency ranges.

IV. PAPERS PUBLISHED, TO BE PUBLISHED, AND SUBMITTED

1. T. Chang, G. B. Crew, and J. M. Retterer, "Electromagnetic Tornadoes in Space: Ion Conics Along Auroral Field Lines Generated by Lower Hybrid Waves and Electromagnetic Turbulence in the Ion Cyclotron Range of Frequencies," to be published in Computer Physics Communications, North Holland, Netherlands, 1987.

2. J. M. Retterer, T. Chang, G.B. Crew, J.R. Jasperse, and J. D. Winningham, "Monte Carlo Modeling of Ionospheric Oxygen Acceleration by Cyclotron Resonance with Broad-Band Electromagnetic Turbulence," Physical Review Letter, 59, 148, 1987.

3. D. Tetreault, "Double Layers on Auroral Field Lines," submitted to Geophysical Research Letters.

4. D. Hastings, A. Barnett, and S. Olbert, "Radiations from Large Space Structures in Low Earth Orbit with Induced AC Currents," submitted to Journal of Geophysical Research.

5. G.B. Crew and T. Chang, "Lower Hybrid Ion Conics," Physics of Space Plasmas, 6, 55, 1987.

6. J.M. Retterer, T. Chang, G.B. Crew, J.R. Jasperse and J.D. Winningham, "Monte Carlo Modeling of Ion Conic Acceleration by Cyclotron Resonance with Broadband Electromagnetic Turbulence," Physics of Space Plasmas, 6, 97, 1987.

D. Tetreault, "Steady State MHD Clump Turbulence," submitted to Physics of Fluids, 1987.

7. G.B. Crew and T. Chang, "Kinetic Treatment of Oxygen Conic Formation in the Central Plasma Sheet by Broadband Waves," in Huntsville Workshop on Magnetosphere-Ionosphere Plasma Models, ed. by T. Moore (American Geophysical Union, Washington, D.C., 1987).

8. J.M. Retterer, T. Chang, G.B. Crew, J.R. Jasperse and J.D. Winningham, "Monte Carlo Modeling of Large-Scale Ion-Conic Generation," in Huntsville Workshop on Magnetosphere-Ionosphere Plasma Models, ed. by T. Moore (American Geophysical Union, Washington, D.C., 1987).

9. G.B. Crew, T. Chang, J.M. Retterer and J.R. Jasperse, "Simulation of Oxygen Conic Formation," Proceedings of the Third International School for Space Simulation, ISSS-3, Part 2, 22, 1987.

10. J.M. Retterer, T. Chang and J.R. Jasperse, "Two-D Simulation and Theory of Ion and Electron Acceleration by VLF Turbulence in the Suprauroral Region," Proceedings of the Third International School for Space Simulation, ISSS-3, Part 2, 22, 1987.

11. M. Andre, "Transverse Ion Heating in the Polar Cusp Region," submitted to Geophysical Research Letters.

V. PAPERS PRESENTED

1. American Physical Society, 1986 Fall Meeting of the Division of Plasma Physics, T. Chang, G.B. Crew, N. Hershkowitz, J.R. Jasperse and J.D. Winningham, "Modeling of O^+ Conics in the Magnetospheres".

2. American Physical Society, 1986 Fall Meeting of the Division of Plasma Physics, G.B. Crew and T. Chang, "Similarity Model of Ion Conic Formation".

3. American Geophysical Union, 1986 Spring Meeting, G.B. Crew and T. Chang, "Kinetic Treatment of Oxygen Conic Formation in the Central Plasma Sheet by Broadband Alfven Waves".

4. American Geophysical Union. 1986 Fall Meeting, G.B. Crew and T. Chang, "Similarity Model of Ion Conic Formation".

5. American Geophysical Union, 1986 Fall Meeting, J.M. Retterer, T. Chang, G.B. Crew, J.R. Jasperse and J.D. Winningham, "Ion Conics: Case Study of Two Acceleration Mechanisms".

6. International School on Space Simulations, T. Chang, G.B.Crew and J.M. Retterer, "Simulation and Theory of Heavy Ion Acceleration", 1987.

7. International School on Space Simulations, G.B. Crew, T. Chang, J.M. Retterer and J.R. Jasperse, "Simulation of Oxygen Conic Formation", 1987.

International School on Space Simulations, J.M. Retterer, T. Chang and J.R. Jasperse, "Two-D Simulation and Theory of Ion and Electron Acceleration by VLF Turbulence in the Supraauroral Region", 1987.

8. Huntsville Workshop on Magnetosphere-Ionosphere Plasma Models, J.M. Retterer, G.B. Crew, T. Chang and J.R. Jasperse, "Monte Carlo Modeling of Oxygen Ion Acceleration by Broadband Electromagnetic Ion Cyclotron Resonance", 1987.

9. Huntsville Workshop on Magnetosphere-Ionosphere Plasma Models, G.B. Crew and T. Chang, "Kinetic Treatment of Oxygen Conic Formation in the Central Plasma Sheet by Broadband Waves", 1987.

10. Huntsville Workshop om Magnetosphere-Ionosphere Plasma Models, J.M. Retterer, T. Chang, G.B. Crew, J.R. Jasperse and J.D. Winningham, "Monte Carlo Modeling of Large-Scale Ion-Conic Generation", 1987.

11. International Union on Radio Science, 1988 National Meeting, T. Chang, "Electromagnetic Tornadoes in Space".

12. 1987 Cambridge Workshop in Theoretical Geoplasma Physics and Chapman Conference on Plasma Waves and Instabilities in Magnetospheres and at Comets, M. Andre, "Transverse Ion Heating in the Polar Cusp Region".

13. 1987 Cambridge Workshop in Theoretical Geoplasma Physics, D. Tetreault, "Double Layers on Auroral Field Lines".

14. 1987 Cambridge Workshop in Theoretical Geoplasma Physics, J. Retterer, J. R. Jasperse, and D. Decker, "A Kinetic Model for the Diffuse Aurora".

VI. INVITED LECTURES

1. Invited Lecture at the Annual Meeting of the American Physical Society-Division of Plasma Physics, Baltimore, MD (November 1986)
   "Ion Acceleration in the Magnetosphere by Broad Band Lower Hybrid Waves (LHW) and Electromagnetic Turbulence in the Ion Cyclotron Range of Frequencies (ICRF)" by Tom Chang

2. Review Lecture at the Third International School for Space Simulations, Beaulieu, France (June 1987)
   "Simulation and Theory of Heavy Ion Acceleration" by Tom Chang

3. Invited Lecture at the 22rd General Assembly of the International Union on Radio Science, Tel Aviv, Israel (September 1987)
   "Ion Acceleration in the Magnetosphere by Broad Band Lower Hybrid Waves and Electromagnetic Turbulence in the Ion Cyclotron Range of Frequencies" by Tom Chang

4. Seminar given at the Naval Research Laboratory, Washington, D.C. (March 1987)
   "Ion Acceleration in the Magnetosphere by Broad Band Lower Hybrid Waves(LHW) and Electromagnetic Turbulence in the Ion Cyclotron Range of Frequencies" by Tom Chang

5. Seminar given at Dartmouth College (October 1987)
   "Electromagnetic Tornadoes in Space" by Tom Chang

6. Seminar given at the University of Cincinnati (April 1987)

   "Stochastic Heating of Charged Particles by Plasma Waves" by Tom Chang

7. Invited Lecture given at the 1987 Cambridge Workshop on Theoretical Geoplasma Physics (July 1987)

   "Double Layers on Auroral Field Lines" by D. Tetreault

8. Invited Lecture given at the 1987 Cambridge Workshop on Theoretical Geoplasma Physics (July 1987)

   "A Kinetic Model for the Diffuse Aurora", by J.M. Retterer, D.T. Decker, and J.R. Jasperse

9. Seminar given at the Dartmouth College (October 1987)

   "MHD Clump Turbulence", by D. Tetreault

VII. PROFESSIONAL PERSONNEL ASSOCIATED WITH THE PROGRAM

Tom T. S. Chang, Director

Geoffrey B. Crew, Coordinator for Computing Facilities and Research Staff

John Belcher, Professor

Stanislaw Olbert, Professor

D. Tetreault, Research Scientist

Peter Yoon, Postdoctoral Scientist

Fareed Yaseen, Postdoctoral Scientist

Alan Barnett, Postdoctoral Scientist

J. K. Chao, Visiting Professor

J. R. Jasperse, Visiting Scientist (without renumeration)

J. M. Retterer, Visiting Scientist

M. Andre, Visiting Scientist

J. D. Winningham, Visiting Scientist

A. Hamza, Graduate Student and Research Assistant

Jay Johnson, Graduate Student and Research Assistant

VIII. SCIENTIFIC INTERACTIONS

1. Ion Heating, plasma theories, symposia and workshops

   J.R. Jasperse,, AFGL

2. *Quasilinear diffusion* theories and ionosphere-magnetosphere coupling processes

   C. Dum, Max-Planck Institute for Extraterrestrial Physics, Germany

3. Plasma waves, parametric processes and auroral double layers

   H. Koskinen, Finish Meteorological Institute

4. Plasma waves, ion acceleration and mode conversion processes

   M. Andre, Swedish Space Institute

5. Nonclassical polar wind, ion acceleration, polar cap particle precipitation

   J.D. Winningham, Southwest Research Institute

6. Ion acceleration and plasma waves

   W. Peterson, Lockheed Research Laboratory

7. Plasma waves

   M. Mellott, R. Huff and D. Gurnett, University of Iowa

8. Plasma waves and ion acceleration

   P. Kintner, Cornell University

9. Nonclassical polar wind

   J.K. Chao, Center for Space and Remote Sensing Research, Taiwan

10. Monte Carlo and particle-in-cell simulations, ion acceleration, particle diffusion, nonclassical polar wind and polar cap sub-visual arcs

J.M. Retterer, Space Data Analysis Laboratory, Boston College

11. Nonlinear electromagnetic plasma turbulence in the ion cyclotron range of frequencies

I. Roth, Space Sciences Laboratory, University of California, Berkeley

12. Acceleration of ionospheric ions in the auroral zone at ionospheric altitudes

A. Yau, Herzberg Institute, Canada

13. Renormalization group and path integral techniques applied to ionospheric plasma turbulence

D. Vvedensky, Imperial College, London

14. Electromagnetic Waves and Ion Conics

R. Erlandson, Applied Physics Laboratory, John Hopkins University

IX. VISITORS

1. Professor Hannes Alfven (Nobel Laureate), University of California at San Diego and the Royal Institute of Technology, Sweden

2. Professor Christian Dum, Max-Planck Institute for Extraterrestrial Physics, Garching, Germany

3. Dr. J. R. Jasperse, Air Force Geophysics Laboratory

4. Professor C. S. Wu, Institute for Science and Technology, University of Maryland

5. Dr. Hannu Koskinen, Finish Meteorlogical Institute, Finland

6. Dr. Mats Andre, Swedish Space Institute

7. Dr. D. Vvedensky, Imperial College, England

8. Professor George Siscoe, University of California at Los Angeles

9. Dr. J. M. Retterer, Space Data Analysis Laboratory, Boston College

10. Dr. Raymond Pottelotte, CRPE, France

11. Dr. A. Yau, Herzberg Institute, Canada

12. Dr. I. Roth, University of California, Berkeley

13. Dr. J. D. Winningham, Southwest Research Institute

14. Professor J. K. Chao, Center for Space and Remote Sensing Research, Taiwan

15. Professor R. Lysak, Department of Physics and Astrophysics, University of Minnesota

X. CONFERENCES ORGANIZED

1. 1987 MIT Symposium on the "Physics of Space Plasmas." This conference is sponsored jointly by the MIT Center for Space Research, AFGL, and the Marlar Fund. A total of approximately 150 scientists participated including the Nobel Laureate, Professor Hannes Alfven and over fifty researchers from the Air Force Geophysics Laboratory. Co-conveners are: Tom Chang, J.R. Jasperse and J. Belcher.

2. 1987 Cambridge Workshop in Theoretical Geoplasma Physics: Ionosphere-Magnetosphere-Solar Wind Coupling Processes. This workshop is sponsored jointly by the MIT Center for Theoretical Geoplasma Physics (established under the AFSOR-URI program) and AFGL. A total of 135 scientists and students from the U.S., England, Germany, Sweden participated including a large contingent from the Air Force Geophysics Laboratory.

3. 1988 Cambridge Workshop in Theoretical Geoplasma Physics: Polar Cap Dynamics and High Latitude Ionospheric Turbulence. This workshop will be co-sponsored by the MIT Center for Theoretical Geoplasma Physics and AFGL with active participation from the Naval Research Laboratory and NASA.

1987 Seventh Annual MIT Symposium on 1987

PHYSICS OF SPACE PLASMAS

DATE AND TIME: January 9, 1987, 8:30 - 17:30 (Friday)

LOCATION: Room 37-252 (Marlar Lounge) Center for Space Research

ORGANIZED BY: J. Belcher, T. Chang, J.R. Jasperse

MASTER OF CEREMONY: J. Binsack (MIT)

COFFEE, TEA AND DANISH: 8:30 - 9:00

SESSION I: Chairperson: T. Chang 9:00 - 9:40

1. **"Welcoming Remarks"** — **H. Carlson (AFGL)**
2. **"Plasma Universe"** — **H. Alfven (RIT/Sweden & UCSD)**

COFFEE AND TEA: 9:40 - 10:30

SESSION II: Chairperson: J.R. Jasperse (AFGL) 10:30 - 12:00

1. "The Solar Wind Coupling Problem with Solutions" — G. Siscoe (UCLA)
2. "Viking Observations of Intense Electrostatic Hiss Bands in the Source Region of Auroral Kilometric Radiation" — R. Pottelette (CRPE/France)
3. "The Effect of the Magnetospheric Electric & Magnetic Fields on the Average Characteristics of the Auroral Zone" — D.A. Hardy/ M.S. Gussenhoven-Shea (AFGL)

COMPLIMENTARY LUNCH & VOYAGER MOVIE (URANIAN ENCOUNTER) 12:00 - 13:00

SESSION III: Chairperson: J. Belcher (MIT) 13:00 - 14:30

1. "An Overview of the Uranian Magnetosphere" — J. Belcher (MIT)
2. "Pick-up Protons Seen Near Comet Halley" — A. Lazarus (MIT)
3. "Plasma Circulation in Arbitrary Oriented Magnetospheres" — R. Selesnick (MIT)

COFFEE AND TEA: 14:30 - 15:00

SESSION IV: Chairperson: W. Burke (AFGL) 15:00 - 16:30

1. "Solutions of the linearized Balescu-Lenard-Poisson Equations for a Weakly-Collisional Plasma: Some New Results" — J.R. Jasperse B. Basu (AFGL)
2. "Detailed In-Situ Observations of Low-Altitude Perpendicular Ion Acceleration" — A. Yau (Herzberg Inst. NRC Canada)
3. "Gyroresonance Heating of Central Plasma Sheet O^+-Conics by Lefthand Polarized Waves" — T. Chang (MIT)

CLOSING REMARKS: B. Coppi (MIT) 16:30 - 16:40

POSTER PAPERS:
- Mathematical Details of Paper IV-1 — J. Jasperse/B. Basu (AFGL)
- Details of Paper IV-3 — T. Chang/G. Crew/J. Retterer/ J. Jasperse

WINE AND CHEESE PARTY 16:40 - 17:30

For Further Information, Contact:

Dr. Tom Chang (617) 253-7523
Dr. G. Crew (617) 253-3789
Jana Buchholz (617) 253-7555
MIT Center for Space Research
Cambrige, MA 02139

Dr. J. R. Jasperse
Air Force Geophysics Laboratory
Hanscom AFB MA [illegible] [illegible]

SECOND ANNOUNCEMENT

1987 CAMBRIDGE WORKSHOP IN THEORETICAL GEOPLASMA PHYSICS

THEME:

IONOSPHERE-MAGNETOSPHERE-SOLAR WIND COUPLING PROCESSES

LOCATION: MIT CAMPUS, CAMBRIDGE, MA USA

DATES JULY 28 - AUGUST 1, 1987

WORKSHOP FORMAT:

- Morning tutorials: Two one-hour lectures each morning to be delivered by G. Siscoe (UCLA) and R. Lysak (U. Minnesota). These lectures will survey the current status of the various micro-, meso-, and macro-scale coupling processes among the ionosphere, magnetosphere, and the solar wind.

- Afternoon invited lectures on current topics and workshop. Invited speakers and panel moderators will include:

M. Ashour-Abdalla	A. Hasegawa	M. Silevitch
R. Bergmann	R. Kaufmann	R. Spiro
R. Boström	L. Lee	B. Sonnerup
W. Burke	W. Lotko	M. Temerin
J. Craven	J. Lyon	D. Tetreault
G. Crew	R. McPherron	V. Vasyliunas
N. Crooker	P. Palmadesso	R. Walker
C. Dum	J. Retterer	R. Wolf
C. Goertz	R. Schunk	

- Evening poster sessions.

This workshop is sponsored by the MIT Center for Theoretical Geoplasma Research (established under the AFOSR-URI program) and AFGL.

A limited number of scholarships will be available to qualified graduate students.

Prospective participants are invited to submit abstracts of poster papers outlining their current research activities on or before May 31, 1987. Abstracts should be prepared in the AGU format.

Additional registration forms may be obtained from Tom Chang, Center for Theoretical Geoplasma Research, MIT Center for Space Research, Room 37-271, Cambridge, MA 02139; Telephone number: 617/253-7527; Telex Number: 92-1473

FIRST ANNOUNCEMENT

1988 CAMBRIDGE WORKSHOP IN THEORETICAL GEOPLASMA PHYSICS

THEME:

POLAR CAP DYNAMICS AND HIGH LATITUDE IONOSPHERIC TURBULENCE

LOCATION: MIT CAMPUS, CAMBRIDGE, MA USA

DATES: JUNE 13-17, 1988

WORKSHOP FORMAT:

- Morning tutorials.
- Afternoon invited lectures on current topics and workshop.
- Evening poster sessions.

This workshop is sponsored by the MIT Center for Theoretical Geoplasma Physics (established under the AFOSR-URI program) and AFGL.

Proceedings of this workshop will be published as Volume 8 in the SPI *Conference Proceedings and Reprint Series* by Scientific Publishers, Inc.

Additional information may be obtained from Tom Chang, Center for Theoretical Geoplasma Research, MIT Center for Space Research, Room 37-271, Cambridge, MA 02139; Telephone number 617/253-7527; Telex Number: 92-1473.

XI. PROCEEDINGS EDITED

1. "Physics of Space Plasmas (1985-7)," Ed. by T. Chang, J. Belcher, J.R. Jasperse and G. Crew, Scientific Publishers, Inc. 1987.

2. "Ion Acceleration in the Magnetosphere and Ionosphere", AGU Monograph Number 38, Editor-in-Chief: T. Chang, Co-editors: J.R. Jasperse, M.K. Hudson, R.G. Johnson, P.M. Kintner, M. Schulz, and G. Crew, American Geophysical Union, Washington, DC, 1986

3. "Ionosphere-Magnetosphere-Solar Wind Coupling Processes," SPI Conference Proceedings and Reprint Series, Vol. 7, Co-editors: T. Chang, G. B. Crew, and J. R. Jasperse, to be published by Scientific Publishers, Inc.

XII. COMPUTER CAPABILITIES

The past year has seen a dramatic improvement in the computer support facilities of the Center for Theoretical Geoplasma Physics. We have acquired a stand-alone configuration of SUN workstations, which have proven ideally suited to the range of our Center's needs.

At the heart of our configuration is a SUN 3/260C-8 color workstation configured with more than half a gigabyte of disk memory. This machine has a floating point performance of better than 0.1 Mflops which has proven acceptable for adequate response from typical interactive numerical analysis codes. It provides disk support for two client workstations, a SUN 3/110LC-4 and a SUN 3/50M-4 which provide additional access and computing capacity. In addition, a number of PC computers are connected to these Sun workstations.

The workstations are run under a UNIX operating system which provides a rich spectrum of system utilities and capabilities. Notable among these is the fact that we are connected via a high-speed ethernet to similar machines within the Center for Space Research. This allows for the partitioning of large tasks among many workstations for improved interactive performance. It has also spawned interdisciplinary interactions that have been most fortuitous. For example, we have learned how to adapt image processing software designed for radar altimetry data to the analysis of plasma dispersion and distribution functions. Another bonus of this computing environment is in the high level of support for text processing activities. This has led to greater efficiency in the publication of papers as well as enabling us to organize workshops and publish proceedings with minimal impact on scientific output.

Finally, via our CSR ethernet connection, we are also connected to the main campus and the outside world, including Arpanet, Spannet and Bitnet. In addition, we have a high-speed (56Kbps) link to the NSF John von Neumann supercomputer center at Princeton for access to the CYBER 205 where we perform our most demanding computer simulations. We also have access to the Cyber machine at the Air Force Geophysics Laboratory.

XIII. SUMMARY

It has been exactly one calendar year since the establishment of the MIT Center for Theoretical Geoplasma Physics under the sponsorship of the AFOSR-URI program. The Center's accomplishment during the year is quite impressive. We are now fully staffed with fifteen participating faculty, staff, postdoctoral and graduate students, and visiting scientists. Throughout the year, we have kept a continuing and active interaction with the Air Force Geophysics Laboratory, particularly through the interactions with Drs. J. R. Jasperse and H. Carlson, as well as other renowned research and academic institutions around the globe.

Jointly with AFGL, we have sponsored a Symposium on the Physics of Space Plasmas and a Workshop on Ionosphere-Magnetosphere-Solar Wind Coupling Processes. Another workshop on Polar Cap Dynamics and High Latitude Ionospheric Turbulence is being planned. Two sets of proceedings have been published under the joint editorship of MIT and AFGL.

We have established a new Hannes Alfven Lecture series in honor of Professor Alfven, a Nobel Laureate in Space Plasmas. Professor Alfven has also agreed to visit our center regularly to provide academic leadership and added prestige to our organization.

Over one dozen original research papers have been produced during the year under the AFOSR-URI sponsorship. All of these papers contained unique, innovative ideas of theoretical geoplasma analyses capable of explaining some of the outstanding puzzling problems in geoplasma physics as discovered by direct spacecraft observations.

During the year, the group has presented numerous scientific papers and invited talks at various national/international conferences and eminent research and academic institutions.

Our computing facilities have been greatly enhanced to support innovative interactive programming as well as the capability of undertaking the sophisticated computer simulations that are at the forefront of numerical modelling of space plasma physics.

We have established a proceedings series in Geoplasma Physics, each of which will include tutorial articles on subjects of current interest in ionospheric-magnetospheric research. We have also established a Geoplasma Seminar series with lectures delivered by outstanding established scientists covering both the theoretical and experimental aspects of space plasma physics.

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