EARLY RESULTS FROM THE ACTIVE MAGNETOSPHERIC PARTICLE TRACER EXPLORERS (AMPTE) SATELLITE EXPERIMENTS

Over the past several months, the Active Magnetospheric Particle Tracer Explorers (AMPTE) satellite experiments, conducted by APL, the Max Planck Institute for Extraterrestrial Physics (MPE) of West Germany, and the Rutherford Appleton Laboratories (RAL) of the United Kingdom, have reached a number of important milestones in both the active and passive program phases. These include the first artificial ion injection experiments into the solar wind on September 11 and 20, 1984; the creation of a barium artificial comet on December 27, 1984; and more recently a number of barium and lithium releases on the nightside of the earth's magnetosphere. The last remaining active experiment took place on July 18, 1985, when a second barium artificial comet was created on the dusk side of the earth's magnetosphere.

The active experiments and the passive observations and measurements of the earth's plasma environment have produced many new scientific results. A special all-day session of the American Geophysical Union's Annual Spring Meeting in Baltimore on May 31, 1985, presented results obtained from August 16, 1984 (the launch date) through early March 1985. The session abstracts are reprinted below from *EOS* **66**, 350-353 (1985). They illustrate the variety of new observations obtained by the three AMPTE spacecraft so far. Following the abstracts are three tables reprinted from the *Technical Digest* (Vol. 4, No. 1) that identify the several AMPTE experiments and the team investigator of each.

A special issue of *Geophysical Research Letters* summarizing the first-ever measurements of the composition of the earth's ring current has recently been published (May 1985). In addition, a special issue on AMPTE of the *IEEE Transactions on Geoscience and Remote Sensing* (May 1985) gives a comprehensive description of the AMPTE spacecraft, detector systems, and ground-based data centers, together with preliminary results from all experiments flown on AMPTE. Thirteen papers describing the results from the solar wind releases have been submitted to the *Journal of Geophysical Research* and are expected to appear in a special issue in January 1986.

STAMATIOS M. KRIMIGIS

Overview of Li and Ba Plasma Injections in the Solar Wind

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In 1984 three plasma injection experiments were performed by the AMPTE Ion Release Module (IRM) in the solar wind. The phenomena observed in situ by the plasma and field instruments on board the IRM and its United Kingdom Subsatellite include: creation of a magnetic cavity; a strong compression of the magnetic field and draping of the field lines around the cavity; electron heating; ion acceleration by the solar wind electric field, which is strongly modified in the injection region; a slowing down of the solar wind flow; and excitation of various types of plasma waves after maximum compression of the magnetic field. The case of the Ba-injection optical observations from aircraft and the ground complemented the diagnostics. Main unexpected findings are: absence of any microturbulence in the narrow current layer shielding the magnetic cavity; stability of the barium cloud against flute-type perturbations; creation of a halo of hot (≤ 200 eV) Ba ions surrounding the magnetic cavity; fast extraction of ions from the main cloud by electric polarization fields. The last effect determined the short lifetime of 5 minutes of the artificial comet.

Ground-Based Imaging of the AMPTE Artificial Comet

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The imaging system in Boston University's Mobile Ionospheric Observatory (MIO) was used to observe the AMPTE "artificial comet" experiment of 27 December 1984. The MIO was deployed at a site in Boulder Canyon (40.02°N, 105.33°W), hoping to add a north-south leg to the east-west baseline established by major instrumental facilities at Kitt Peak (AZ) and White Sands (NM). Extensive cloud cover prevented observations from the two prime sites, and thus the data set from Boulder resulted in the only appreciable measurements made from the ground.

Immediately following the release at 12:32:00 UT, the CCD-based camera system in the MIO used short integration times (1/30 sec), without a filter in the system, to observe the rapid expansion of the bright barium cloud against the faint stellar background. By 12:33:02 UT, the white light image reached its maximum size of ~6 arc min, or ~200 km in diameter, giving an average expansion speed of 1.7 km/sec.

When the white light images faded at 12:34 UT a 4554A filter was inserted into the system to isolate the emission generated by the barium ion cloud. Using integration times of 5 to 20 seconds, images at post-release times of 3′08″, 3′43″ and 4′31″ showed the formation maturity and disintegration of a beautiful cometary-type head and tail system. By 5′08″, the artificial comet disappeared from the MIO detection system.

The diamagnetic cavity produced during the initial expansion phase appears to have formed sooner and smaller than anticipated. The high solar wind pressure and compression of the magnetic field on the sunward side of the cavity rapidly disrupted the cloud, with the dilution of the plasma being so extensive the Doppler-induced intensity enhancements were not observed.

Doppler Imaging of the AMPTE 'Artificial Comet' Release

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Gerhard Haerendel (Max-Planck-Institut für Extraterrestrische Physik)

Duncan Bryant (Rutherford Appleton Laboratory)

Images of the artificial comet release on Dec. 27, 1984, were obtained using a Doppler Imaging system. These images show that barium ions become heated rapidly as they leave the diamagnetic cavity, which is comprised of cold barium ions. The heating to energies of 200 eV occurs within a narrow boundary layer less than 200 km in thickness. The images allow the motion of the region of cold plasma relative to the two spacecraft to be determined, in addition to defining the region of hot barium plasma surrounding both spacecraft. Mass shedding is apparent. The hot barium plasma is accelerated antisunward from a region in which ion densities of 10 to 50 cm^{-3} exist. Secondly, tail rays form at the edges of the cold plasma cloud. When these tail rays detach from regions on the periphery of the cold plasma cloud, the barium ions are quite hot ($\sim$ 200 eV). Within a region of up to 4000 km from the comet head discrete tail features fluctuate by up to 20 degrees from the antisunward direction and become accelerated antisunward from different regions around the periphery of the cold ion cloud. The heating rates, the mass loss rate and the acceleration rates are compared with theoretical model predictions for the prevailing solar wind conditions and the mass loading appropriate to the barium ion cloud.

Tracer Aspects of Li and Ba Releases in the Magnetosphere and Its Vicinity

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A release of $\sim 10^{25}$ Li atoms was made on September 11 and again on the 20th, 1984 by the AMPTE Ion Release Module (IRM) spacecraft at a geocentric distance of $\sim 18.8\ R_e$ in the subsolar direction, creating an ion cloud $\sim 5\ R_e$ in diameter. Detailed modeling of ion propagation to the bow shock and transport through the magnetosheath shows that $\gtrsim 20\%$ (September 11) and $\gtrsim 50\%$ (September 28) of the ions mapped to a 9 R_e^2 area around the stagnation point on the magnetopause. The AMPTE Charge Composition Explorer (CCE) satellite, located inside the magnetosphere at an apogee 8.78 R_e, inclination 4.8° at a local time $\sim$0100 MLT, was to detect Li ions over the energy range a few eV to $\gtrsim$6 MeV. Detailed analysis of the data for the several hours following the Li releases shows that few, if any, Li ions reached the location of the CCE; upper limits to the Li flux at $L \geq 8$ are ~ 3 to 5 $(cm^2 \cdot sec \cdot sr)^{-1}$ in the range 25-300 keV/e (Li/H $\leq 2 \times 10^{-5}$), ~ 0.2 to 2 $(cm^2 \cdot sec \cdot sr)^{-1}$ in the range 315-750 keV (Li/H $< 10^{-4}$), and $\sim 7 \times 10^{-3}$ to 0.2 $(cm^2 \cdot sec \cdot sr)^{-1}$ at $E \geq 750$ keV. These upper limits are less by factors of 2 to $>$ 30 than the Li fluxes estimated by using previously measured plasma sheet ion spectra. Additional releases of Ba and Li are planned in the magnetotail during windows on March 21-29, and April 11-28, 1985. The implications of these results will be discussed in the context of current theoretical models of plasma entry, convection, and drift into and through the magnetosphere.

AMPTE's Lithium Releases in the Solar Wind

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Simultaneous magnetic field measurements obtained from the IRM and UKS ($\sim$ 30 km upstream from the IRM) during the two lithium releases performed in September of last year are described. The IRM and UKS monitor the local interaction of the lithium ions with ambient solar wind. It is shown that the releases result in the formation of a tangible obstacle to the solar wind and an associated magnetic cavity (seen only by the IRM) from which the interplanetary field is excluded. Outside the cavity the field is gradually compressed until eventually the cavity is convected downstream. We also compare our observations with other relevant interactions and emphasize the unique features of this particular experiment.

Plasma Observations on AMPTE/IRM for the Lithium and Barium Releases in the Solar Wind

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In this paper we investigate Li and Ba releases in the solar wind, as they appear in the measurements of ions and electrons above 20 eV and 15 eV, respectively, made with the MPE/UCB fast 3D-plasma experiment on AMPTE/IRM. For the Li releases, the dominant effects are the pick-up of the newly created Li ions by the solar wind electric field and the heating of electrons. When first observed, the beam of Li ions is substantially broadened, probably as a result of its interaction with the solar wind. Later on, when the Li density has decreased, the Li beam becomes narrower than can be resolved by the instrument. The development of the maximum ion energies up to about 1 keV is a measure of the cloud expansion speed. Shortly after the Li releases, while the spacecraft is still inside the cloud's magnetic cavity, hot ($E > 70$ eV) electrons are observed. Their density and temperature are further enhanced when entering the magnetic field compression region, consistent with adiabatic heating. In contrast to the simple crossed-beam situation during the Li releases, the Ba release results in a much more complex ion behavior. Effects of gyration, gradient drifts, polarization fields, and Ba ion pickup all appear to contribute to the situation. As with the Li releases, electron heating is again observed to start while inside the cloud's magnetic cavity, even though wave activity is much reduced there.

Observation of He^+ Pick-Up Ions in the Solar Wind

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He^+ pick-up ions in the energy range 5 to 40 keV have been observed in the solar wind using the Max-Planck-Institut/University of Maryland time-of-flight spectrometer SULEICA on AMPTE/IRM. The helium ions show a distinct ring distribution in the solar wind frame, although a weak scattering has broadened the distribution. From the absolute ion flux of about 50 ions/cm^2s a column density of neutral helium upstream of the spacecraft is derived. The value exceeds the density of exospheric helium by more than two orders of magnitude. A possible contribution from the ring current to the helium density is small. Interstellar neutral helium seems to be a promising source for the pick-up ions.

Early Time Interaction of Lithium Ions with the Solar Wind in the AMPTE Mission

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The early time interaction of an artificially injected lithium cloud with the solar wind is simulated with a one-dimensional hybrid code. Simulation results indicate that the lithium cloud presents an obstacle to the solar wind flow, forming a shock-like interaction region. Several notable features are found: (1) The magnetic field is enhanced up to a factor of about 6 followed by a magnetic cavity downstream. (2) Solar wind ions are slowed down inside the lithium cloud with substantial upstream reflection. (3) Most of the lithium ions gradually pick up the solar wind velocity and move downstream. (4) Intense and short-wavelength electric fields exist ahead of the interaction region. (5) Strong electron heating occurs within the lithium cloud. (6) The solar wind convection electric field is modulated in the interaction region. The simulation results are in remarkable agreement with in situ spacecraft measurements made during lithium releases in the solar wind by the AMPTE (Active Magnetospheric Particle Tracer Explorers) Program.

Plasma Observations within Ion Clouds

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Within each of the chemical releases performed in the solar wind three dimensional measurements of positive ions and electrons were made at two points; one between the two canisters from which the release is made and one far from the release site compared with the distance between the canisters. Despite the different conditions of the release some common features are found; formation of a magnetic cavity, acceleration of the released ions outside the cavity, heating of electrons, deceleration and deflection of the solar wind.

The three releases will be contrasted and some explanations of the phenomena put forward.

Numerical Simulations of Ba- and Li-Plasma Injections in the Solar Wind

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A hybrid code treating the ions as particles and the electrons as a massless fluid is applied to the numerical simulation of the interaction of Li- and Ba-plasmas with the solar wind. A 1-D model exhibits strong enhancements of the magnetic field in front of the plasma clouds and strong electron heating. The solar wind protons are reflected by an electric polarization field. Although all these features are expressed in the actual observations, they are exaggerated by the one-dimensionality of the model. A two-dimensional code with the magnetic field being transverse to the direction of flow and either within or perpendicular to the simulation plane has been developed as well. These models show a slowing down and deflection of the solar wind by the clouds and a magnetic compression that is in much better agreement with the observations.

Plasma Wave Observations During the AMPTE Lithium and Barium Releases

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Numerous plasma wave phenomena were observed by the AMPTE-IRM spacecraft following the solar wind lithium and barium releases in September and December 1984. As the ion cloud expanded over the spacecraft, plasma oscillations near the local electron plasma frequency provided measurements of the local plasma density. For the lithium releases the peak electron density at the IRM was about 10^5 cm^{-3}, and for the barium release the electron density exceeded 5×10^5 cm^{-3}. Following the initial jump the electron density decayed approximately as t^{-2} as the cloud expanded. Cosmic radio noise and kilometric radio emissions from the earth were prevented from entering the cloud at frequencies below the electron plasma frequency. The location of these cutoff effects suggests that the plasma cloud has a shell-like configuration with a reduced-plasma density in the central region. Within the diamagnetic cavity formed by the cloud narrow band electrostatic emissions were observed at the local ion plasma frequency. Also, a broadband burst of electrostatic noise occurred at the boundaries of the cavity. Upstream of the diamagnetic cavity an intense burst of electrostatic noise was observed with characteristics very similar to noise observed in the earth's bow shock. This noise is believed to be caused by a beam-plasma interaction between the injected ions and the rapidly moving solar wind ions.

Upstream VLF Waves Seen Following the AMPTE Plasma Releases

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Three active plasma releases in the solar wind have been studied in which either Li or Ba ions form a magnetic cavity which excludes the solar wind. Upstream of these dense ion clouds the solar wind encounters a bow shock reminiscent of the Earth's bow shock, although in the case of AMPTE it appears to be an electrostatic shock. Further upstream of this intense electrostatic shock is a region of plasma waves related to the ion cloud/solar wind interaction. This paper will discuss the characteristics of these upstream waves which appear to also be basically electrostatic in nature. The frequency range extends from a few Hz up to several kHz with a well defined upper cutoff frequency which decreases in time/distance from release. A theoretical interpretation for the cause of these waves will be presented. Upstream VLF waves from the three solar wind releases have several similarities even though the solar wind conditions were quite different for the releases.

Electron Number Density from the AMPTE/IRM Plasma Wave Experiment During Solar Wind Lithium and Barium Releases

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In September 1984 the AMPTE/IRM spacecraft twice injected a few kg of lithium into the solar wind in front of the Earth's bow shock which were subsequently photoionized. In December 1984 several kg of barium were released outside of the Earth's dawn magnetosheath. The plasma wave instruments on the AMPTE/IRM were used to monitor the electrostatic and electromagnetic fields associated with the injections of the ions into the solar wind. Observations of plasma wave emissions at the electron plasma frequency were used to determine the electron number density as a function of time. These data provided valuable information on the degree of ionization, ionization rate, and density profile as a function of position inside the diamagnetic cavity that was formed. The cavity lasted for 11 and 7 seconds for the September 9 and 20 releases, respectively. For each of these releases the observed electron number density as a function of time after the release was proportional to about t^{-2} until the spacecraft approached the edge of the cavity and the number density increased. At one second into each lithium release the electron number density exceeded 2×10^4 cm^{-3}. The electron number density profile for the December 27 barium release was qualitatively similar but the cavity lasted for nearly 80 seconds and the number density one second into the release exceeded 10^6 cm^{-3}. In addition to determining the electron number density at the spacecraft the plasma wave data also provided information on number density remote from the IRM by observing the shadowing of electromagnetic radiation.

AMPTE UKS Wave and Particle Measurements Made During Ion Releases in the Solar Wind

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Lithium injection experiments were performed by AMPTE-IRM at 0725 on September 11 and 0956 on September 20, 1984. A barium release took place at 1232 on December 27, 1984. AMPTE-UKS was close to the IRM and detected the interaction between the natural and artificial plasmas. Significant results include evidence of wave-particle interactions, energization of the injected ions and mass loading of the solar wind.

Magnetic Field Observations of AMPTE's Artificial Comet

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On 27 December 1984 IRM released a cloud of Barium atoms in the solar wind region on the dawn flank of the magnetosphere. Data recorded by the magnetometers on both spacecraft (IRM and UKS, ~170 km apart) are described. For several minutes the Ba^+ ions form an obstacle to solar wind flow. A magnetic hole (B ~0.02 nT) is detected by the IRM for more than one minute, created by the expanding ion cloud. On the upstream side of the cavity the solar wind field is highly compressed by more than a factor of 10. We also discuss the implications of these results in natural cometary encounters.

Fluctuations in the Solar Wind at the Lithium Ion Gyrofrequency

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Some five minutes after the Lithium release conducted on 25th September 1984, after Lithium ions could no longer be detected by UKS, and after the solar wind had apparently returned to pre-release conditions a second event was observed.

As in the events immediately following the release the solar wind was decelerated and deflected. The event appears to be linked to the release itself because there was a series of quasi-periodic fluctuations at the Lithium ion gyrofrequency.

Electron Cyclotron Harmonic Waves Observed by the AMPTE-IRM Plasma Wave Experiment Following a Lithium Release in the Solar Wind

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An unexpected occurrence following the second lithium release by the AMPTE-IRM spacecraft in the solar wind was the appearance of electron cyclotron harmonic (ECH) emissions. These emissions began about 50 sec after the release and continued for several minutes. Narrow band emissions were present in each of the first five harmonic bands. Broadband emissions were also present. The broadband emissions extended from below the electron gyrofrequency to above the highest ECH band. Both emissions were entirely electrostatic because no accompanying signals were detected from the magnetic antenna. Candidate instabilities include the ion acoustic and the electron cyclotron drift instability. These instabilities would be driven by the lithium ions accelerated to relatively high energies perpendicular to the solar wind magnetic field by the electric field in the lithium plasma cloud.

An Ion Beam-Plasma Instability for Explaining the Electrostatic Noise Associated with the AMPTE Solar Wind Ion Releases

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During the AMPTE (Active Magnetospheric Particle Tracer Explorers) solar wind ion releases in September and December, 1984, an intense burst of electrostatic noise was observed near the upstream edge of the ion cloud. A linear stability analysis using realistic parameters shows that the electrostatic noise can be accounted for by an ion beam-plasma instability caused by the solar wind proton beam streaming through the nearly stationary ion cloud. The model used assumes that the hot solar wind electrons and the cold electrons associated with the ion photoionization drift at a velocity intermediate between the injected ion velocity and the solar wind proton velocity. The drift velocity is determined by the condition that the net current be zero. The analysis assumes Maxwellian velocity distributions for all components. The results show that two instabilities can be excited, one with phase velocities near the solar wind proton drift velocity, and the other near the drift velocity of the ion injected ions. The instability near the injected ion velocity has the highest growth rates and appears to be the least sensitive to the various parameters involved. The growth rate is largest when the injected ion density and the solar wind proton density are similar, which explains why the noise only occurs near the upstream edge of the ion cloud.

Elemental and Charge Composition of Ring Current Ions

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Mass and charge-state measurements of major ion species have been made for the first time in the bulk of the ring current preceding and during the strongly asymmetric, non-typical geomagnetic storm of Sept. 4-7, 1984. Using data from the University of Maryland/Max-Planck Institut, Lindau Charge-Energy-Mass (CHEM) Spectrometer on the CCE Spacecraft, we examine the differential energy spectra, energy densities (u) and number densities (n) in the energy range ~1 to 300 keV/e for H^+, O^+, He^+, He^{++}, O^{++} and (C+N+O) with charge states above 3. We find that the prestorm ring current consists primarily of ions of solar wind origin ($n_{He^{++}}/n_{H^+}$ = 0.019) with O^+ contributing <5% to the total energy density. Following the sudden commencement and upon reentry of CCE into the magnetosphere a few hours later (at L ~7.5) substantial flux increases are detected for all ring current ions, the most pronounced for O^+. The storm-time energy densities of H^+, O^+, O^{++}, He^+ and He^{++} at L = 3.7 to 4.7 (maximum $-\Delta B$ at CCE) are 68, 28, 2.5, 1.6 and 0.9 percent respectively of the total energy density of 3×10^{-7} ergs/cm^3. Typical average energies ($E \equiv u/n$) of storm-time ring current ions range from 45 keV/e for O^+ to 70 keV for protons. We observe 1-300 keV/e, high charge state heavy ions (CNO, Si, Fe) with abundances similar to those in the solar wind, implying that the entry and acceleration of solar wind ions does not depend strongly on the mass or charge of the ions. We conclude that in response to the compression of the magnetosphere, in addition to an increase in the number density, energy density and average energy of all ring current particles (which may be roughly accounted by the decreased volume of the compressed magnetosphere), there is a strong and almost immediate (< few hours) injection of energetic ions, (O^+, O^{++}, He^+) of ionospheric origin.

Energetic Magnetospheric Heavy Ion Populations
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The Medium Energy Particle Analyzer (MEPA) on the AMPTE CCE spacecraft measures near-equatorial ion flux and angular distributions over an energy range from 25 keV to > 6 MeV, and ion composition in a telescope that measures time-of-flight and total energy down to thresholds of 56 keV for protons, 18 keV/nucleon for helium, 9 keV/nucleon for oxygen and ~15 keV/nucleon for the silicon group and iron, extending composition measurements to lower energies than previously possible. In addition to protons, helium and oxygen, significant magnetospheric fluxes of carbon, the Ne-Mg-Si group, and (for the first time) iron nuclei have been seen over most orbits since launch. Heavy nuclei fluxes have been studied over the period of September 16 through October 9, 1984. Magnetospheric fluxes of both iron nuclei and the Si group over the energy range of 15 to ~100 keV/nucleon are present essentially throughout each orbit, with spin-summed flux levels ranging from ~1 to >200 (cm^2 sec sr)$^{-1}$. Pitch-angle distributions are strongly peaked near 90°. Heavy nuclei fluxes at L > 4 exhibit both short term (less than one hour) and long term (many days) variability (as do oxygen nuclei over the same energy ranges). Average heavy fluxes tend to increase slightly from apogee (L ~ 9) toward lower L, but drop abruptly inside L ~ 3.5. On at least 8 occasions in this interval the magnetopause moved inward of the CCE location as determined by the onboard magnetometer. In each case heavy ion fluxes immediately dropped below the level of detectability (~0.1 (cm^2 sec ster)$^{-1}$), recovering only when the magnetopause moved back out past the CCE. Thus these ions, though presumably of solar wind origin, are accelerated to the observed energies within the magnetosphere and represent a true magnetospheric population.

Pitch Angle Distributions of Energetic Protons, Helium, and Oxygen in the Storm-Time Ring Current
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Energetic protons (E > 56 keV), helium (E > 72 keV) and oxygen (E > 137 keV) are sampled by the Medium Energy Particle Analyzer (MEPA) on board the Charge Composition Explorer (CCE) in 32 angular sectors perpendicular to the CCE spin axis, providing good coverage of pitch angles. The near-equatorial angular distributions of these ion species have been examined during the geomagnetic storm commencing on September 4, 1984. It is found that in the range 3.2 < L < 4.1, during the main phase of the storm, the pitch angle distributions of protons, helium, and oxygen show a "head and shoulder" shape. This is characterized by a distinct and broad flux enhancement centered at 90° pitch angle, a sharp flux decrease at a pitch angle some tens of degrees away from 90°, and a slow variation in flux from that pitch angle to the edge of the loss cone. This feature is similar to the shape of pitch angle distribution occasionally seen in energetic electrons (E ~ 20 - 500 keV) which have been attributed to the difference in the pitch angle diffusion between Landau resonance and electron cyclotron resonance (Lyons et al., 1972). During the same CCE orbit, in the range 2.7 < L < 3.1, "butterfly" distributions are seen in energetic protons in the energy range of 56 - 190 keV but not at higher energies. Other features in the angular distribution of these ion species will also be presented and discussed.

Detection of Energetic (> 100 keV) Molecular Ions in the Earth's Magnetosphere
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Information concerning the composition of energetic ions in the Earth's magnetosphere is important for identifying plasma sources and establishing plausible scenarios for acceleration. The UMD/MPAE Charge-Energy Mass (CHEM) spectrometer on the AMPTE/CCE spacecraft has been returning new composition results in the energy range 1-300 keV/e. Analysis of ring current data from a storm time period in early Sept. 1984 indicates that in addition to the expected atomic ions (H^+, O^+, O^{++}, He^+, He^{++}), molecular ions with M/Q in the range 28-32 were also present at energies up to well above 100 keV/e. These molecular ions may be identified as some combination of N_2^+, NO^+, and O_2^+, all of which have been detected previously in the upper ionosphere. From a preliminary study of the CHEM data, there is also an indication of an energetic ion with M = 2, Q = +1 at a level of ~0.1% of H^+ during this storm period. The possible identifications are H_2^+ or D^+, and, if this result is confirmed by further analysis, the presence of either of these species at this level is quite surprising.

Energetic N^+ Ions in the Magnetosphere
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G. Kremser, W. Stüdemann, and B. Wilken (Max-Planck-Institut für Aeronomie)

We present the first measurements of energetic (~100 keV) N^+ ions obtained from the UMD/MPAE Charge-Energy-Mass (CHEM) spectrometer on the AMPTE/CCE spacecraft shortly after its launch on 16 Aug 1984. CHEM employs the combined techniques of electrostatic deflection, time of flight and total energy measurements to obtain the mass, charge and energy of incident ion. In its normal operating mode CHEM covers the energy range 1-300 keV/e in 32 steps. As part of its post-launch turn-on sequence CHEM was commanded into a fixed energy per charge step. Although no information on energy spectra is available in this mode, it does provide substantially greater pulse height statistics (factor of 32) at the chosen step. Analysis of the several days of pulse height data while CHEM was in this mode clearly indicates the presence of N^+ ions. The ratio of N^+ to O^+ (at ~100 keV) was found to be somewhat larger than expected with a value of ~0.2 when integrated over L-values of ~3 to 9.

Mass Dependent Ion Angular Distributions Below 17 keV/e in the Storm-Time Ring Current
D. M. Klumpar and E. G. Shelley (Lockheed Palo Alto Research Laboratories, Space Sciences)

The Hot Plasma Composition Experiment on the AMPTE/CCE satellite has measured the near equatorial ion composition over the energy per charge range from 0.03 to 17 keV in the magnetosphere. Pitch angle distributions of the major ionic constituents in the equatorial ring current during various phases of magnetic storms provide an important means of identifying possible source variations of these ions. Analysis of the data reveals differences between H^+ and O^+ that suggest mass dependent injection, transport, and/or loss processes. During the main phase of one magnetic storm, the 12-17 keV H^+ ions had a trapped distribution qualitatively consistent with inward convection from the plasma sheet, while the O^+ was dominated by ions with equatorial pitch angles less than 90° suggesting that a significant fraction of these ions had been injected onto their drift shells closer to the earth. The existence of such mass dependent distributions has implications on past interpretations of distributions measured without mass discrimination.

Charge and Pitch Angle Distributions of Magnetospheric Ions: Initial Results from AMPTE-CCE Observations
B. Wilken, G. Kremser, and W. Stüdemann (Max-Planck-Institut für Aeronomie)
G. Gloeckler, F. M. Ipavich, and D. C. Hamilton, (Department of Physics and Astronomy, University of Maryland)
D. Hovestadt (Max-Planck-Institut für Extraterrestrische Physik)

The CHEM-spectrometer on board the AMPTE-CCE spacecraft allowed for the first time a complete characterisation of the major ions in the magnetospheric plasma. CHEM measurement established the presence of highly ionized carbon and oxygen ions presumably of solar wind origin as well as substantial fluxes of O^+ and O^{+2} which appear to be injected from the ionosphere. Charge- and pitchangle distributions of oxygen, carbon and helium ions will be presented and discussed.

AMPTE/CCE Magnetic Field Studies of the September 4, 1984 Storm
T. A. Potemra (OSTP, Executive Office of the President)
L. J. Zanetti (Applied Physics Laboratory, The Johns Hopkins University)
M. H. Acuña (Goddard Space Flight Center, National Aeronautics and Space Administration)

A large geomagnetic storm began on September 4, 1984 with a SSC reported at 07:46 UT. Observations acquired with the AMPTE/CCE Magnetic Field Experiment have been used to determine the overall magnetic field environment during the evolution of this storm. The CCE spacecraft had reached apogee at 06:05 UT on the same day and was moving slowly inward in the afternoon sector. At approximately 06:33 UT, when the spacecraft was at a 8.8 R_e geocentric radial direction, a ~30% increase in total field was observed which is interpreted as a sudden impulse (si). The magnetic field observed by CCE remained relatively stable and northward until 07:45 UT when it began to fluctuate over a wide range of frequencies up to the 50 Hz limit of the instrument. At least six magnetopause crossings were observed that were separated by approximately 20 to 25 min. Magnetopause normals were estimated from these crossings, and were found to be approximately constant in direction. This suggests that the entire magnetosphere was "breathing" in and out with a period of about 45 min. The magnetic field variation stopped abruptly at approximately 10:00 UT when CCE was at a 7.5 R_e radial distance, indicating that the magnetopause was displaced inward to at least this distance. A comparison of observed and theoretical magnetic fields for a series of CCE passes near perigee revealed the development of a significant and asymmetric ring current during the period following the SSC. The local time distribution of DST as well as the in situ particle measurements confirm at least two separate developments of ring current disturbances at dusk without any symmetry until well after the storm recovery.

Observation of Energetic Molecular Ions in the Outer Magnetosphere

B. Klecker, D. Hovestadt, E. Möbius, and M. Scholer (Max-Planck-Institut für Extraterrestrische Physik)

G. Gloeckler and F. M. Ipavich (Department of Physics and Astronomy, University of Maryland)

We present first measurements of energetic molecular ions in the outer magnetosphere. The observations were made with the suprathermal energy ionic charge analyzer (SULEICA) on AMPTE/IRM in the outer ring current region (R ~6-7 R_E) during the magnetic storm on Sept. 4, 1984. Molecular ions with a mass per charge ratio of ~32 (most probably O_2^+ and NO^+ ions) have been identified in the energy range 40-160 keV/q and a ratio $(O_2^+ + NO^+)/O^+$ ~0.07 has been observed. These molecular ions of ionospheric origin probably have been accelerated during the magnetic storm. For quiet time conditions so far only an upper limit of < 1% has been derived for the $(O_2^+ + NO^+)/O^+$ ratio.

The Laminar Structure of the Dawn Magnetopause

D. S. Hall, D. A. Bryant, and C. P. Chaloner (Rutherford Appleton Laboratory)

A. J. Coates, A. D. Johnstone, D. J. Rodgers, and M. F. Smith (Mullard Space Science Laboratory, University College London)

R. P. Rijnbeek and D. J. Southwood (Blackett Laboratory, Imperial College of Science and Technology)

It has become clear that the magnetopause is not the simple boundary it was once supposed. We observe that while the magnetic field gives a clear signature of a magnetopause crossing, the plasma signatures are complex and do not in general coincide spatially with the magnetic boundary crossing.

The AMPTE mission has given an opportunity to investigate the flanks of the magnetosphere in high resolution. We present here observations by the 3-D ion and electron spectrometers and the magnetometer on the AMPTE-UKS spacecraft made in the day-side and dawn-side magnetopause boundary layers.

We discuss the relationship of the boundary to the governing solar-wind and magnetospheric parameters.

Small-Scale Structure of Magnetospheric Boundaries

D. J. Southwood and R. P. Rijnbeek (Blackett Laboratory, Imperial College of Science and Technology)

In addition to the active phase of the AMPTE mission, which consists of performing and monitoring the local effects of ion releases, the IRM and UKS routinely provide high space and time resolution measurements of the natural plasma regions and boundaries encountered along their orbits. The UKS is particularly well-equipped to study the Earth's magnetopause in greater detail then before since 3-D ion and electron distributions (10 eV to 20 keV energy range) are obtained once every 5 seconds (the UKS spin period). Already this has led to important progress in our understanding of solar wind-magnetosphere transfer processes.

So far, the IRM and UKS has provided comprehensive coverage of the magnetopause on the day-side and on the dawn flank. We show data from some typical crossings and report the occurrence of quasi-steady reconnection and closely related but more impulsive and patchy reconnection signatures, with particular reference to the 4 September 1984 pass, which occurred under extremely disturbed magnetic conditions. Also, we show that reconnection occurs on field-amplitude and time scales smaller than have been reported previously and give examples of the close relationship between plasma flow and magnetic field signatures at the magnetopause.

AMPTE CCE instrumentation

Instrument	*Coverage*	*Measurement Technique*	*Investigator Team*	
Plasma composition measurement spectrometer	Ion composition, 0 eV/q to 17 keV/q	Retarding potential electrostatic analyzer; $E \times B$ analyzer	E. Shelley (L.I.) R. Sharp, R. Johnson, W. Peterson	LPARL
			J. Geiss, P. Eberhardt, H. Balsiger, A. Ghielmetti	U. Bern
	Electrons, 50 eV to 25 keV	Magnetic analyzers	D. Young	LANL
			G. Haerendel	MPE
			H. Rosenbauer	MPAE
Charge energy mass spectrometer	Ion composition, ~ 1 keV/q to 300 keV/q	Electrostatic analyzer; time-of-flight and total E	G. Gloeckler (L.I.), F. Ipavich	U. Md.
			B. Wilken, W. Stüdemann	MPAE
			D. Hovestadt	MPE
Medium energy particle analyzer	Ion composition, 0.01 to ≳ 1.0 MeV/nucleon	Time-of-flight and total E	R. McEntire (L.I.), S. Krimigis, A.T.Y. Lui	APL
Magnetometer	DC to 50 Hz	Vector fluxgate	T. Potemra (L.I.)	APL
			M. Acuña	GSFC
Plasma wave spectrometer	AC E fields, 5 Hz to 178 kHz	Electric dipole	F. Scarf (L.I.)	TRW, Inc.

L. I., Lead investigator
LPARL, Lockheed Palo Alto Research Laboratory
U. Bern, University of Bern, Switzerland
LANL, Los Alamos National Laboratory
MPE, Max Planck Institute for Extraterrestrial Physics
MPAE, Max Planck Institute for Aeronomy
U. Md., University of Maryland
GSFC, NASA/Goddard Space Flight Center

AMPTE IRM instrumentation

Instrument	*Coverage*	*Measurement Technique*	*Investigator Team*	
3-D plasma analyzer (ions and electrons)	~0 to 25 eV 10 eV to 30 keV	Retarding potential analyzer; 2 symmetrical quadrispheres	G. Paschmann (L.I.), N. Schopke C. Carlson	MPE UCB
Mass separating ion sensor	0.01 to 12 keV/q	Quadrispherical E/q analysis; magnetic analysis	H. Rosenbauer (L.I.), H. Grünwalt, M. Witte, H. Goldstein	MPAE
Suprathermal energy ionic charge analyzer	10 to 300 keV/q	Electrostatic analyzer; time-of-flight and total E	D. Hovestadt (L.I.), E. Möbius, M. Scholer, B. Klecker F. Ipavich, G. Gloeckler	MPE U. Md.
Magnetometer	DC to 50 Hz	Vector fluxgate	H. Lühr (L.I.), N. Klöcker B. Häusler M. Acuña	TUB MPE GSFC
Plasma wave spectrometer	*E:* DC to 5 MHz *B:* 30 Hz to 1 MHz	42 m (tip-to-tip) antenna; 2 boom-mounted search coils	B. Häusler (L.I.), R. Treumann D. Gurnett, R. Anderson R. Holzworth H. Koons	MPE U. Iowa U. Wash. AEROSP
Li/Ba release experiments	8 Li release canisters (52 kg); 8 Ba release canisters (108 kg)	CuO thermite reaction	A. Valenzuela (L.I.), H. Föppl, E. Rieger, G. Haerendel, O. Bauer	MPE

UCB, University of California at Berkeley
TUB, Technical University of Braunschweig
AEROSP, Aerospace Corp.

IRM UK subsatellite instrumentation

Instrument	*Coverage*	*Measurement Technique*	*Investigator Team**	
3-D ion analyzer	0.01 to 20 keV/q	Electrostatic analyzer	A. Johnstone	MSSL
3-D electron analyzer	25 eV to 25 keV	Electrostatic analyzer	D. Hall, C. Chaloner	RAL
Particle modulation analyzer	~ 1 Hz to ~ 1 MHz	Electron and ion signal processing	M. Gough	U. Sussex
Magnetometer	DC to 10 Hz	Vector fluxgate	D. Southwood, S. Cowley C. Russell	ICST UCLA
Plasma wave spectrometer	*E:* 0 to 128 kHz	7 m tip-to-tip probe	L. Woolliscroft P. Christiansen	U. Sheffield U. Sussex
	B: 30 Hz to 20 kHz spot frequency to 2 MHz	Boom-mounted search coil	M. Gough D. Jones	U. Sussex BAS

MSSL, Mullard Space Science Laboratory
RAL, Rutherford Appleton Laboratory
ICST, Imperial College of Science and Technology
UCLA, University of California at Los Angeles
BAS, British Antarctic Survey

*D. A. Bryant is lead investigator for the UKS science payload.