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CONICAL ION DISTRIBUTIONS AT ONE EARTH RADIUS - OBSERVATIONS FROM THE ACCELERATION REGION?

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ABSTRACT

Thermal ion measurements from the Retarding Ion Mass Spectrometer (RIMS) on Dynamics Explorer 1 (DE 1) in the night side auroral region were surveyed for evidence of ion acceleration. The RIMS measurements showed evidence for ion acceleration in the 2-10,000 km altitude range, with ion distributions peaked near 90°, and with temperatures of 1 to 10 eV. Two illustrations of the RIMS data for such observations are given here. The conical distributions are found at the low latitude edge of the auroral region, just outside the plasmapause. In the first example, the three major ion species (H+, He+, and 0+) show evidence of acceleration. The angular distributions are peaked at different pitch angles, indicating that the different species have been accelerated at different altitudes. The H+ flux is higher than the 0+ flux in this first example, in the RIMS energy range (0-50 eV). This is apparently typical of the RIMS observations on the night side. In the second example, only O^+ is transversely accelerated.

INTRODUCTION

One of the most intriguing elements of the upper ionosphere has been the observations of ion acceleration in the polar cap, near one earth radius altitude. Beginning with the observations from the S3-3 satellite, it was found that H+ and 0+ were being accelerated upwards with energies of 1-10 keV, over the night side auroral region/l/. This report was followed by observations of transversely accelerated ions over the polar cusp, near local noon/2/. These latter observations, again in the 1-10 keV energy range, showed H+ and O+ with pitch angle distributions peaked between 90° and 180°, which were consistent with ion distributions which had been transversely accelerated at lower altitudes, and were flowing upwards along the magnetic field lines, while conserving their magnetic moments. These observations were made by a mass spectrometer with a low energy limit of 500 eV. A complementary set of measurements, beginning at 90 eV, were made by the electrostatic analyzers on the same satellite/3/. These observations showed low energy (E < 400 eV) conics were concentrated on the dayside for low magnetic activity (Kp ≤ 3), and that most of the conics were in the lowest energy range of the survey. Nightside conics were more common during periods of high magnetic activity (Kp ≥ 3).

Observations at lower energies, and altitudes, were provided by the ISIS 1 and ISIS 2 satellites /4/. Electrostatic analyzer data from less than 10 eV to about 15 keV were obtained from 574 km to 3575 km (ISIS 1) and 1400 km (ISIS 2). The transversely accelerated ion (TAI) observations were found to peak on the night side at 1400 km, in auroral regions. At higher altitudes (2750 to 3550 km), ISIS 1 data indicated that the highest probability was in the dayside, near the polar cleft.

The Dynamics Explorer 1 (DE 1) satellite was launched into polar orbit in 1981, providing the next opportunity to observe the polar acceleration regions, and the first opportunity to observe accelerated ion distributions in the thermal energy range. Data from the Retarding Ion Mass Spectrometer (RIMS) were surveyed for evidence of acceleration, based on our knowledge of previous observations. The initial search produced curious results. Expectations of regularly finding 0+ conics in the night side auroral region were not entirely correct, for the 0-50 eV energy range of RIMS. Instead, it was found that all the major ion species were found accelerated together, with relatively few cases of solely 0+. Also, the dominant feature of the data which soon emerged from our early surveys was the existence of 0+ acceleration over the dayside cusp, or cleft region/5/ These observations were consistent with those from S3-3 and ISIS, but substantially more frequent, and at higher flux levels in this new energy range. Much of the ensuing analysis of the RIMS data focused on this phenomenon, and the major contribution the cleft makes to the magnetospheric ion content.

In the presentation which follows, two cases of night-side auroral ion acceleration are shown. The first shows an example of all three of the major ion species (H+, He+, and 0+) accelerated. The second briefly illustrates an example where only 0+ is accelerated, within the RIMS energy range and sensitivity.

OBSERVATIONS

March 2, 1982 - H+, He+, O+

This first example occurred during the outbound portion of the DE orbit, shortly after perigee. The orbit segment is illustrated in Figure 1, in a plot in the meridian plane. The satellite is rising out of the ionosphere, and leaves the region of cold, ram, 0+ (i.e. the ionosphere proper) at an altitude of 1 RE, near L = 3.6, entering a region of conical ion distributions peaked at L = 3.5. The outer plasmasphere is encountered at L = 3.2 or 3.1. Magnetic activity is high on this day. The activity index ΣKp was 50- for the day, and Kp was 8 for this three-hour period. Also, during the previous three hour period, Kp was 8. This is consistent with the extremely low L-shell for the plasmapause. It is important that the satellite be outside the plasmasphere, and above the ionosphere, since high plasma densities apparently prevent the occurrence of conics/4/.

Figure 2 shows the angular distributions for the three main ion species. The detector used for these measurements looks outward radially from the satellite, with an aperture which is ±15° in the spin plane, and ±55° perpendicular to the spin plane/5/. The horizontal axis in Figure 2 is pitch angle. The angular distributions are peaked at angles near 90°. These distributions, therefore, are not ordered by their spin phase, but instead, pitch angle. This is one indication that the ram energy (0.1 to 1 eV) is less than the thermal energy by a substantial ratio - i.e. there is little cold, core plasma at this time.

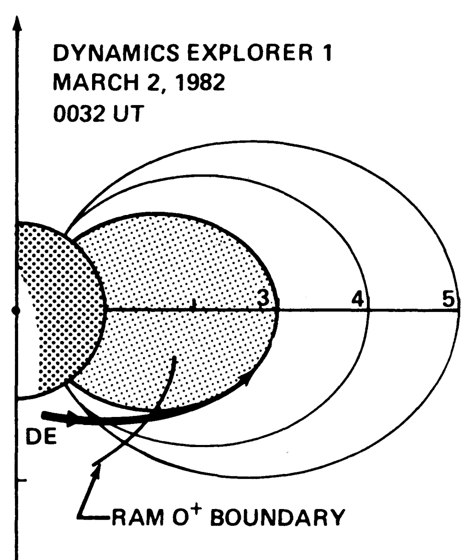

Fig. 1 Orbit plot for Dynamics Explorer 1. The thick solid dark line is the DE-1 The inferred plasmasphere region is shaded inside L = 3. The ionosphere, or ram 0+ boundary is sketched at an altitude of 1 RE.

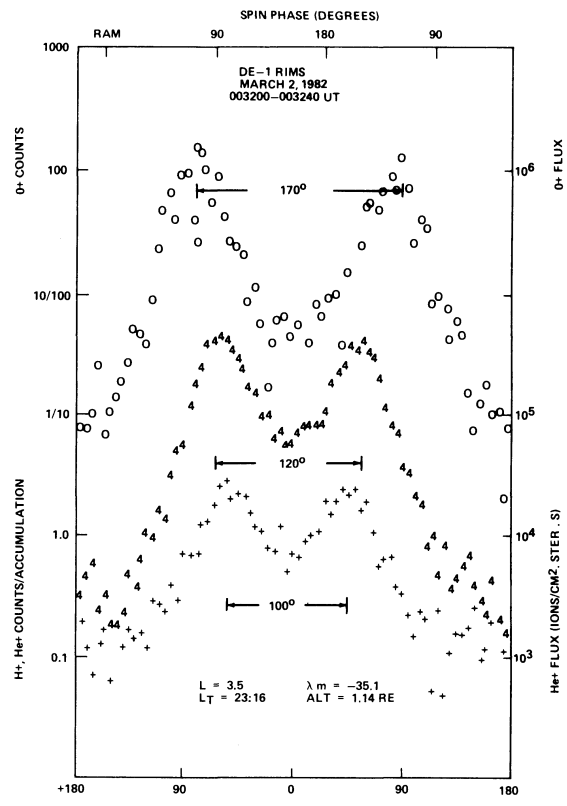

Fig. 2 Spin curves for H+ (+), He+ (4), and 0+ (0). These curves are for integral flux measurements. The upper limit for the H+ flux is several hundred eV, for He+ between 50 eV and 100 eV, and for 0+ approximately 50 eV.

The three species show different angles for their peaks, with the width of the conic increasing with mass. These widths indicate different acceleration heights, as discussed below. The H+ flux appears low, because of degradation of the detector at this time. In fact, the H+ flux at the peak is about 2 x 10^6 ions/cm^2 ster s, about double the O+ flux. RPA analysis of the three ion species using a detector pointing parallel to the spin axis (and hence at 90° pitch angle) gives density and temperature for the three species: H+: n =2 cm^{-3}, T=6.6eV; He+ : n=1cm^{-3}, T=5.leV; O+: n=5 cm^{-3}, T=9.6eV. The differences in H+ and He+ temperature are not significant, given the scatter in the data, but the oxygen temperature is clearly higher than that of the lighter ions. If the angular distributions in Figure 2 are mapped back down to the location where they peaked at 90° pitch angle, we will have an indication of the acceleration altitude, assuming there are no major parallel electric fields at work. Using the model developed to trace the cleft ion fountain /6/, and considering particles of 1, 3, 10, and 30 eV, it was found that O+ has an apparent source only a few hundred kilometers down the field line, while He+ is rising up from 38° magnetic latitude, at 2.0 RE, and the lightest ion, H+, is coming from 40 - 41° magnetic latitude, at 1.8 to 1.9 RE.

These observations are similar to RIMS observations presented previously /5,7/, with one difference. The previously published events (Plate 2 of reference 5 and Plate 2 of reference 7) were relatively long lived, extending for several minutes, i.e., several tenths of RE in altitude, and several degrees in magnetic latitude. The observation presented above is taken from the center of a very short-lived event - 1 to 3 minutes, depending on the ion specie. This is more typical of the conical distributions found to date.

<u>O+ Acceleration</u>

In the initial surveys of the RIMS data, one example has been found where only 0+ is accelerated. Data from 25 September 1983 (day 268), at 2254 UT, show an 0+ conic as the satellite rises from the ionosphere, again during an active day (ΣKp = 34+, Kp = 4). The 0+ conic illustrated in Figure 3 is from the center of a region of similar measurements that extends from 2.1 to 2.7 RE, L = 6.7 to 4.3, 2340-2310 LT. There were negligible fluxes of trapped H+ during this period, and the He+ measurements show a distribution which is peaked along the magnetic field line

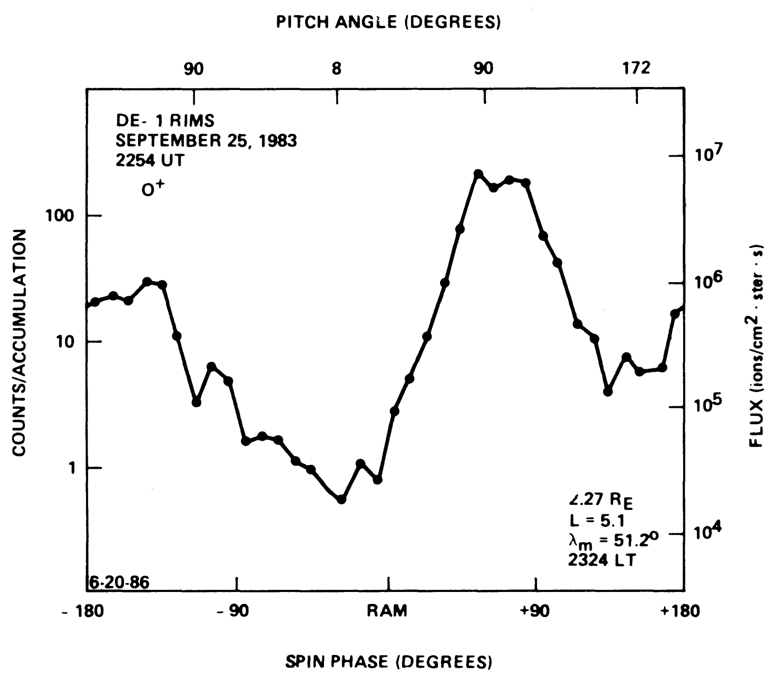

Fig. 3. Spin curve for 0+. The bottom axis is labeled with spin phase, the top with pitch angle. The conical distribution is centered at about 150° spin phase, along the upward field magnetic field line. The difference between the peaks is due to the enhancement in flux caused by ram effects.

(but may be a narrow conical distribution). Figure 3 shows the O+ data from the radial detector, operating in an integral mode which includes O+ fluxes from 0-50 eV. The distribution peaks near 90°-100° pitch angle, with a peak flux of nearly 10^7 ion/cm^2 ster s. The pitch angle distribution remains constant over much of this region, indicating a very broad (in latitude) acceleration region.

Conclusions

The RIMS observations in regions of auroral ion acceleration provide a view of the auroral region which generally agrees with, but differs subtly from previous observations. The major difference is that RIMS measures the simultaneous upward flow of almost every component of the ionosphere, and a relatively high H+/O+ flux ratio. This latter point needs to be investigated further, however, along with a more careful consideration of times when only one ion species is accelerated.

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