SCATHA OBSERVATIONS OF SPACE PLASMA COMPOSITION DURING A SPACECRAFT CHARGING EVENT†

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SUMMARY

During the earth eclipse of the SCATHA spacecraft on 28 March 1979, the spacecraft charged to potentials greater than 1KV for about 30 minutes with extended excursions greater than 4KV. The composition of the hot plasma was obtained in the 0.1 to 32 keV energy range with an ion mass spectrometer aboard the spacecraft. Prior to the onset of the charging event, H^+ was the principal plasma ion, and during the event O^+ was the principal ion. The composition was energy dependent and varied significantly on a time scale of 4 minutes. An assumption that the ion flux was all H^+ would lead to computed number densities that were in error by more than a factor of 2 for several time intervals during the event.

INTRODUCTION

The number density of the hot plasmas that produces spacecraft charging is frequently determined from on-board measurements of the ion fluxes with energies above the spacecraft potential. To determine ion densities from flux measurements, mass composition of the plasmas must be known or assumed. Also, the secondary electron production by keV ions incident on spacecraft surfaces is often strongly dependent on the ion mass. Prior to 1977 when hot plasma composition measurements at high altitudes in the equatorial regions began, it was generally assumed that H^+ was the dominant hot plasma ion (ref. 1). Measurements extending up to 32 keV have now established that O^+ ions are frequently significant contributors to the plasma density and during times of high geomagnetic activity are often the dominant hot plasma ions (ref. 1, 2, 3).

The SCATHA spacecraft has provided the first opportunity near the geostationary spacecraft altitude to obtain the hot plasma composition during spacecraft charging events that produce potentials above a few hundred volts. (The GEOS spacecraft, which also obtained hot plasma composition measurements (ref. 2), did not charge to high potentials.) This report provides composition information during the charging event on 28 March 1979 with a time resolution of 4 minutes.

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OBSERVATIONS AND RESULTS

The SCATHA spacecraft is in a nearly geosynchronous orbit with an inclination of 8 degree, perigee near 27,000 km, and apogee near 43,000 km. The spacecraft is spinning at a rate of about one revolution per minute with its spin axis in the orbital plane.

Hot plasma composition measurements are being obtained in the energy range 0.1 to 32 keV with an ion mass spectrometer aboard the SCATHA spacecraft. The ion energy distributions are measured at 24 energies nearly equally spaced on a logarithmic scale of the energy. The instrument view direction is at 11^{o} to the normal to the spacecraft spin axis and thus is providing data on the pitch angle distributions of the ions. A detailed description of the instrument and its operational modes are contained in an earlier report (ref. 4), and a more general discussion of the SCATHA composition results are presented in a separate paper in this conference (ref. 1).

The charging event on 28 March 1979 began while the SCATHA spacecraft was in an earth eclipse and was coincident with a large enhancement of the energetic electron and ion fluxes (ref. 5). The spacecraft potential during most of the event as determined by Fennel, et al† (ref. 5) is shown in figure 1. It is seen that the potential is highly structured on a time scale shorter than 4 minutes, which is the temporal resolution thus far used for the ion composition determinations in this event. Measurements are made at a higher sample rate but counting statistics have limited the present analysis to 4-minute intervals.

Prior to and during the charging event, H^+ and O^+ were the principal ions in the hot plasma. He^+ and He^{++} ions were near or below the instrument background levels during the event and are not included in this analysis. The O^+/H^+ number density ratio averaged over pitch angle during a 15-minute interval prior to the event is shown as a function of ion energy in figure 2. It is seen that H^+ is the dominant ion above 1 keV with O^+ dominant below 1 keV. When integrated over the instrument energy range (0.1-32 keV), the O^+/H^+ density ratio is 0.86 for this time period. After the onset of the charging event, O^+ became the dominant ion except for the first 4-minute interval. The O^+/H^+ density ratios integrated over the instrument energy range and over pitch angle are shown in the top curve in figure 1 and are tabulated for an extended time period in Table I. From these data, it is seen that an assumption that the ion flux contained only H^+ ions would lead to number densities in error by more than a factor of 2 for several of the time intervals.

As seen in figure 1, there are no obvious correlations between the plasma composition and the spacecraft potential. However, it should be emphasized that the 4-minute averaging of the composition data precludes information on the characteristics of the faster temporal structures in the

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potential as seen in figure 1. In particular, the present analysis does not address the evidence presented by Fennel, et al (ref. 5) that field aligned ions may have some control over the periodic potential variations observed in material samples. The analysis of the plasma composition as a function of pitch angle during charging events is being investigated and will be reported at a later date. However, it is known that for some magnetospheric conditions the composition is strongly dependent on pitch angle (ref. 6 and 7).

The plasma composition is typically energy dependent and it varied significantly during the charging event, even during periods when the change in spacecraft potential was relatively small. This is seen by the data shown in figures 3 and 4 which were adjacent data intervals obtained when the spacecraft was at potentials near 4 KV. The data intervals are labeled A and B in figure 1. An example of the energy dependence when the spacecraft was at lower potential is shown in figure 5 for the time interval labeled C in figure 1. The curves through the data in figures 2 to 4 are least-squared polynomial fits to the points and are included only to indicate the trends in the data.

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TABLE I

O^+/H^+ NUMBER DENSITY RATIOS DURING THE SCATHA SPACECRAFT CHARGING EVENT ON 28 MARCH 1979

UT Seconds	Density Ratio O^+/H^+	UT Seconds	Density Ratio O^+/H^+
59880	0.52	61560	1.55
60120	2.36	61800	1.92
60360	1.17	62040	1.91
60600	1.99	62280	4.67
60840	1.58	62520	4.53
61080	1.33	62760	2.44
61320	2.40	63000	2.41

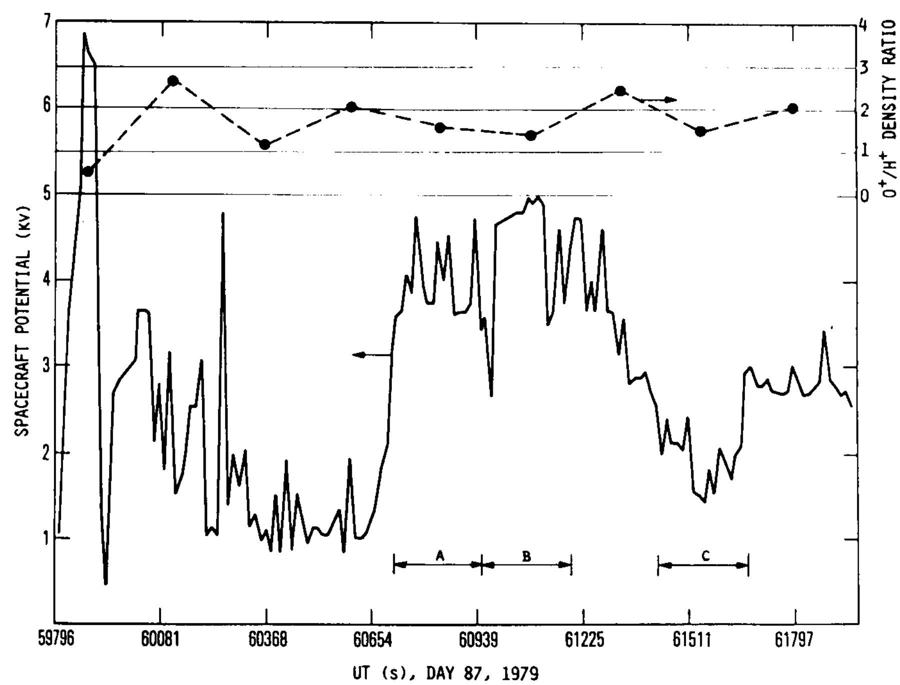

Figure 1. The SCATHA spacecraft potential (ref. 5) and the O^+/H^+ number density ratios of the incident hot plasma ions

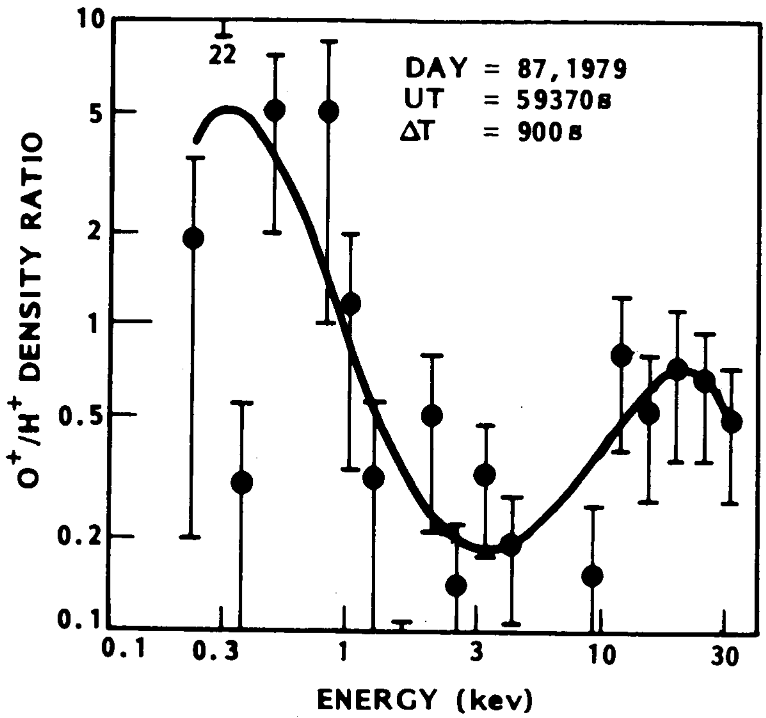

Figure 2. O^+/H^+ number density ratios prior to the SCATHA spacecraft charging event on 28 March 1979.

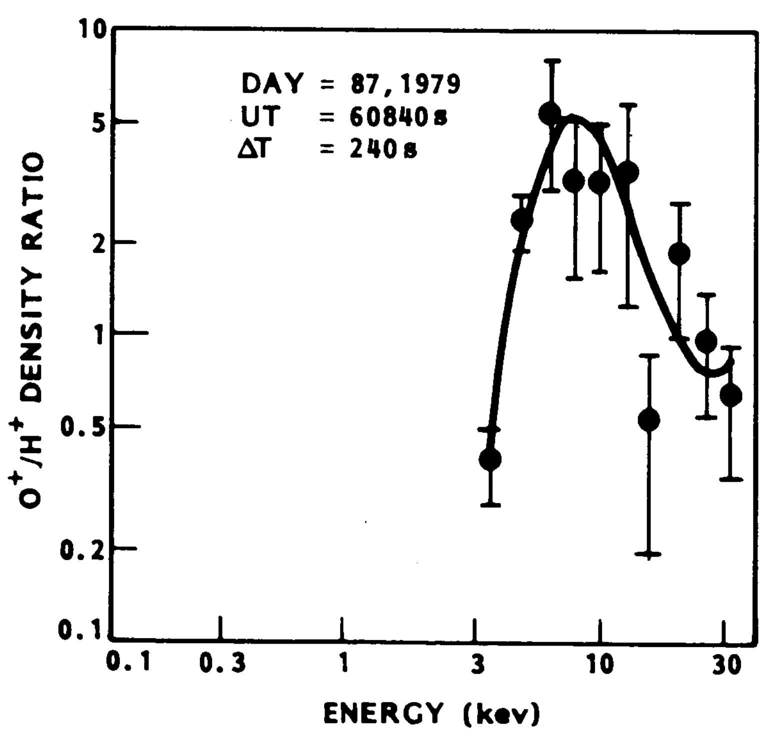

Figure 3. O^+/H^+ number density ratios during the time interval labeled A in figure 1.

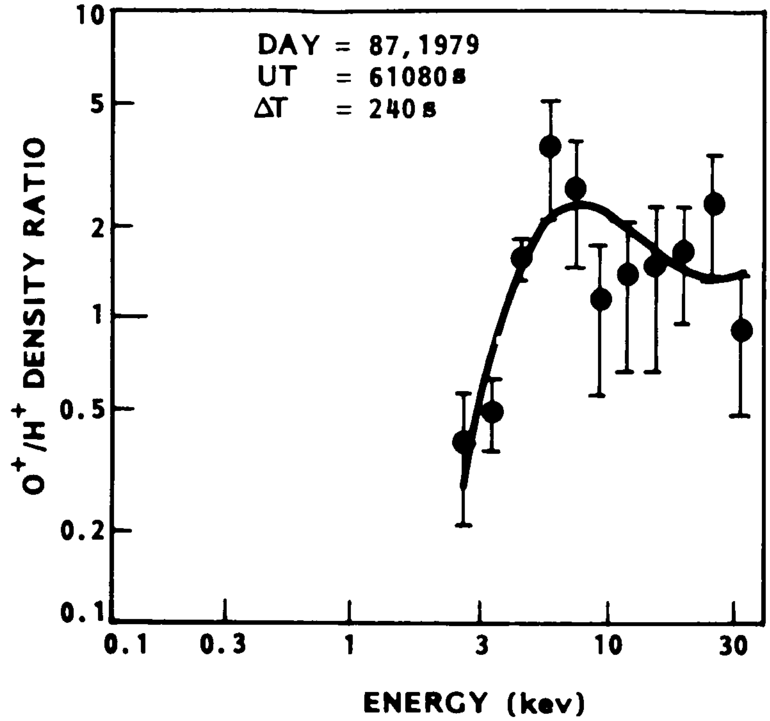

Figure 4. O^+/H^+ number density ratios during the time interval labeled B in figure 1.

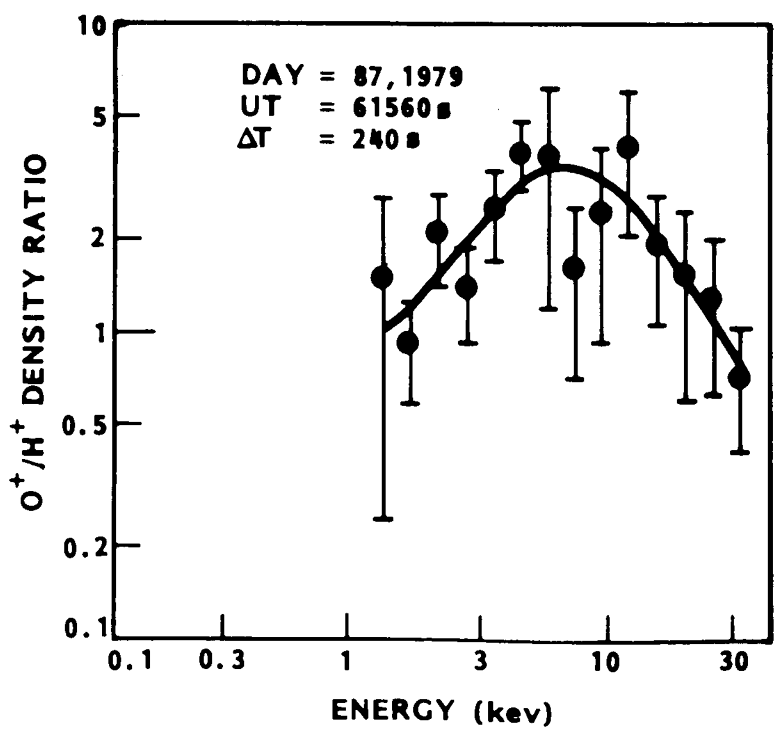

Figure 5. O^+/H^+ number density ratios during the time interval labeled C in figure 1.