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FINAL REPORT

AURORAL ROCKET EXPERIMENT II

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I. INTRODUCTION

This research program was initiated in 1967, under Contract NASW-1474 with two scientific objectives. Firstly, it was desired to conduct a simple and inexpensive flight demonstration of two instruments, developed at this laboratory, for the detection of fluxes of energetic (1-10 kev) neutral hydrogen atoms postulated to exist in the interplanetary medium. Secondly, it was desired that these measurements would provide not just an instrumental test, but significant scientific information. Because an auroral experiment admirably satisfied both objectives, these neutral hydrogen detectors were incorporated into a comprehensive Nike-tomahawk rocket payload. The first rocket, NASA 18:33CE was successfully launched into a post breakup aurora from Ft. Churchill, Manitoba, Canada on 25 April 1968. The results have been reported by *Bernstein et al.* [1969a] and *Wax and Bernstein* [1970].

Because the data from this first flight had only been cursorily analyzed at the time the work supported under the present contract, NASW-1819, was proposed, it was planned that the payload for this flight would consist of the instrument spares from the first flight. However, further analysis of the data indicated several significant results including:

1. The data indicated a non-Poisson distribution in the time of arrival of hydrogen atoms at the detector.
2. The lateral spatial extent of the hydrogen forms was much less than calculated by *Davidson* [1965] for the altitude range at which the observations were made.

3. Measurements of the dispersion in arrival times of hydrogen atoms of different energies at the detector indicated that particle acceleration or precipitation control processes acted at distances <1000 km from the rocket.

4. The hydrogen precipitation showed a non-isotropic pitch angle distribution.

Because of the basic significance of these observations, it was decided to construct a new payload with improved data handling capability and greater coverage of particle precipitation including pitch angle measurements. This payload was successfully launched into an auroral breakup 17 April 1969 and yielded significant evidence for the presence of millisecond fluctuations in precipitated hydrogen and electron fluxes.

Because precipitating 1-10 kev protons will have already achieved or nearly achieved an equilibrium distribution in the various charge states (H^+, H^o, H^-) at Tomahawk apogee altitudes, it is necessary to perform simultaneous measurements of the H^+ and H^o fluxes at higher altitudes in order to determine which is the primary species. Consequently, two, small $H^o - H^+$ energy spectrometers were built for flight on two Javelin rockets assigned to the University of California at Berkeley. These flights were originally scheduled for early 1969, but because of a variety of problems, the flights did not occur until 13 Feb. 1970 and 3 April 1970 from Ft. Churchill. Unfortunately, the present analysis of the data indicates that neither instrument performed satisfactorily during these flights.

II. INSTRUMENTATION, RESULTS, AND DISCUSSION

A. Tomahawk Flight

1. Instrumentation

The particle detectors included (1) an energy independent detector [*Wax and Bernstein,* 1967] for the total energetic hydrogen ($H^o + H^+ + H^-$) flux, (2) an energy spectrometer [*Bernstein et al.*, 1969b] for energetic H^o atoms, (3) an energy spectrometer for energetic protons, (4) an energy spectrometer for energetic electrons, (5) a fixed energy detector for protons parallel to the spin axis, and (6) a fixed energy detector for protons perpendicular to the spin axis. The important characteristics of these instruments, together with their typical observed counting rates are shown in Table I. All the energy spectrometers were basically of the swept single channel variety. The sweep rate was 100 Hz, and permitted the determination of an energy spectrum every 10 msec during periods of high count rates. Scaling circuits, rather than the capacitor storage used in the previous flight, were employed for all detectors.

The neutral hydrogen and proton spectrometers were combined into a single instrument. The neutral channel consisted of a collimator, a set of deflection plates to remove incident charged particles with energy <10 kev, a 2 μgm cm^{-2} carbon foil in which a fraction of the incident neutral beam was stripped and a channeltron detector mounted 180° from the entrance aperture. The proton channel consisted of a collimator only and a channeltron detector mounted 180° from the entrance aperture. The angular separation between the two channels was ∿60°. Laboratory calibrations showed that cross talk, defined as the ratio of the detected counts in the unirradiated channel to those in the irradiated channel, was always $<10^{-3}$; this was considered acceptable for these experiments.

The proton detectors could not distinguish between protons and accelerated ambient ions. However, the efficiencies of both the H^o spectrometer and the total H detector decreased rapidly with increasing atomic number of the incident particle because of increased scattering in the carbon foil. These detectors therefore provided a significant discrimination between precipitated hydrogen and accelerated ambient particles.

In addition to the particle experiments, the payload contained an ac and dc electric field experiment, a two axis aspect magnetometer, an H_β photometer, and a sensitive boom mounted 2 axis flux gate magnetometer for the measurement of local ionospheric current systems associated with the aurora. The last two experiments were supplied under support by the TRW Independent Research and Development Program. The data from these two experiments will not be discussed further since the photometer experiment was apparently unsuccessful and the analysis of the magnetometer experiment data has not been completed.

The ac and dc electric field experiment was approximately identical to that flown on the first Tomahawk flight and was described in detail in the Final Report for Contract NASW-1474 [1968] and by *Bernstein et al.* [1969c]. The significant modifications included a new boom design, and the modification of the dc channel response to provide a linear rather than logarithmic output range. The aspect magnetometer was identical to that flown on the first rocket; a complete description is also found in the Final Report for Contract NASW-1474 [1968].

2. Flight Conditions and Experimental Results

The rocket was launched 17 April 1969 at 0057:30 local time (0657:30 UT) from Ft. Churchill. Beginning about sunset, there was some indication of auroral activity. At ∿0500 UT, there was observable activity to the south appearing as arcs. At 0600 UT, there was major activity on the southern horizon; breakup activity was apparently present there. Subsequently, there was a period of very diffuse patchy type aurora which began to show actively near the zenith. At launch, the patches had formed into a corona display. There was a magnetic bay and a brightening of the aurora. Several minutes after completion of the flight, an extremely bright (the estimated intensity of 5577A was 50-100 KR) and narrow arc developed in the zenith with a nearly north-south alignment. This arc appeared homogeneous. Then the arc dimmed and activity diminished. During the bright arc, there was still evidence of the original coronal display which had shifted to the north.

The launch occurred some three minutes after the magnetic field had reached its maximum depression of 150 gamma. The peak 5577A observed from the ground was ∿14 KR. At times during the flight, the 6300A intensity was comparable to that of 5577A; it reached a maximum intensity of 6.3 KR. There was ≤ 1 db 30 MHz riometer absorption in the breakup event. A

PCA event occurred some five and one half days before this flight, a second event may have possibly occurred four days prior to the flight. On the day of the flight, there was only a very slight indication of the PCA and it is felt that the data reported below were not influenced by any solar cosmic rays.

Both the total precipitated hydrogen and electron fluxes, based on five second averages of the counts, ranged from $10^8 - 10^9$ cm^{-2} sec^{-1} str^{-1}. The energy spectra, shown in Figure 1, fitted well to a power law, E^{-n}, representation with $n = 3.5 \pm 0.4$ for hydrogen and $n = 1.2 \pm 0.6$ for electrons, where the ± indicates temporal variations not the experimental error. A well defined peak was not observed in the electron spectrum. The flux and energy spectrum of the total precipitated hydrogen derived from both the neutral and proton spectrometers are in good agreement, after the raw counting data are corrected by (1) the appropriate efficiency and geometrical factors (Table I) and (2) the extrapolated hydrogen equilibrium fractions in molecular nitorgen given by *Bernstein et al.* [1969a].

Figure 2 shows a two second period of data from the two fixed energy proton detectors and two energy channels of the electron spectrometer. The rocket altitude was approximately 160 km at this time. In this graph, the proton fluxes have not been corrected to the top of the atmosphere. Readily apparent are several abrupt increases of about a factor of 2-4 in the proton count rate associated with larger decreases in the detected electron rate. At approximately the same times, all the electron channels showed abrupt decreases, and all channels of the proton spectrometer and the total hydrogen detector showed increases. Because of the very low counting rate of the H^o spectrometer, an identification of an impulsively increased counting rate is less certain. There did not appear to be any significant change in the energy spectrum of either electrons or hydrogen during the presence of these impulsive events, although there may be a slight tendency in 5 sec average spectra for the neutral and electron spectra to soften during burst periods while the proton spectra remain fixed.

In all the impulsive enhancements we have studied the electron fluxes have decreased. However, it should be noted that because of saturation effects at high count rates in channeltron detectors, an increase in incident flux can result in an observed decreased counting rate. Since the average electron counting rates were generally high, it was thus possible that the observed electron decreases were actually large electron enhancements. In either case, the impulsive character of these events remains valid.

Figure 3 shows one proton burst on an expanded time scale. In general, the characteristics of such proton bursts are (1) the time required to obtain the maximum proton count rate was <4 msec, (2) the proton decay time was usually somewhat longer (~ 30 msec) but sometimes was as long as several tenths of a second, (3) the proton energy spectrum remains nearly unchanged during the burst. Because each electron energy channel was sampled only once every 10 msec, it is more difficult to accurately determine the time required for the electron decrease, but the time appears to be ≤ 10 msec. The electron recovery time was usually somewhat longer than the typical 30 msec proton decay time.

We have carefully considered the possibility that the described phenomena could be the result of payload malfunction rather than events which can be attributed to the aurora. At present, we have concluded that these events were not spurious because vehicle generated noise could not account for the following observations:

1. Although the count rates in the various hydrogen detectors varied over 3 orders of magnitude, the burst enhancements for each of these instruments represented the same relative increase in each detector's count rate. Secondly, the total hydrogen fluxes derived from the proton and from both neutral detectors were in agreement despite the large variations in efficiencies and geometrical factors.

2. The fixed energy proton detector pointed radially to the vehicle spin axis showed the expected large modulation in count rate at the spin frequency. A much smaller spin modulation was seen on the hydrogen detectors parallel to the spin axis. This latter modulation can be caused by a slight misalignment between the detector and the angular momentum vector of the vehicle and is indicative of a non-isotropic pitch angle distribution.

3. Occasionally there was no correlation between bursts observed with the radial proton detector and the forward looking instruments.

4. The high voltage monitor showed no important variation during the reported observations.

5. The energy spectrum of neither the protons nor the electrons changed appreciably during the bursts.

6. The bursts were characterized by an increase in hydrogen flux associated with an apparent decrease in electron flux. Spurious noise counts would always result in increased count rates.

7. An abrupt change in the composition of the energetic particle flux incident on the antenna elements of the E field experiment would result in the observed saturated signals.

It is possible to estimate the extent of the spatial region in which the enhanced hydrogen fluxes were generated by considering the temporal behavior of the various proton detectors.

1. The observed maximum delay of $\sim$0.1 sec between the axial 5 kev fixed proton detector and the 0.28 kev channel of the proton spectrometer indicates a maximum generation distance of $\sim$30 km.

2. Because of its 20% FWHM resolution, the fixed 5 kev proton detectors responded to particles of energy between 4.5 - 5.5 kev. The observed enhancement rise time of $\sim$4 msec thus implies a generation distance of <40 km.

It should be noted that most hydrogen particles have cycled between the neutral and charged state within a few kilometers of the rocket.

The two identical energy (5 kev) fixed proton detectors, one viewing parallel to the rocket spin axis (axial), the other viewing perpendicular to the spin axis (radial) provide our information about the proton pitch angle distribution. The counting rates observed with the radial detector were always a factor of 2 to 4 greater than those observed with the axial detector indicating a larger flux at angles near 90° to the field line. These observations are consistent with those described by *Chase* [1970]. The small spin modulation observed with the axial detector is attributed to a slight misalignment of the instrument collimator with respect to the spin axis, and, as has been noted this modulation is also indicative of a non-isotropic pitch angle distribution.

As the vehicle spun, the radial proton detector measured the pitch angle distribution of protons about the 90° point. As the vehicle precessed, the pitch angle range explored by this detector changed from a minimum range of 85 - 95° up to a maximum range of 75 - 105°. In our analysis of the pitch angle data, care was taken to select portions of the record in which the described burst activity was not present. At the higher altitudes ($\sim\geq 200$ km) the flux observed by the radial detector from the downward hemisphere was comparable to or greater than that from the upper hemisphere. At lower altitudes the downward flux was dominant.

A most interesting feature of the data was the pronounced pitch angle asymmetry observed during some spin cycles. This is clearly shown in Figure 4 which shows the change in this east-west asymmetry during several successive spin cycles. The limitations inherent in a 2 axis aspect magnetometer prevent an identification of east and west for this rocket because it was launched nearly parallel to the field lines. An analysis of those cycles in which this asymmetry is evident, shows that the fluxes from one direction were usually larger. Variations in the angular distribution of protons were very evident on successive cycles. The slow spin rate of ~ 0.7 $\sec^{-1}$ limits the temporal resolution with which rapid fluctuations of pitch angle characteristics can be studied.

In general, the burst repetition rate appeared to range between 0.25 and 2 $\sec^{-1}$ at lower altitudes; above 200 km, the repetition rate increased to 3 - 4 $\sec^{-1}$. In Figure 5, the times of occurrence (and therefore the altitude) versus the angles of the radial detector with respect to the field lines are plotted. The altitude dependence of the recurrence rate is clearly seen. There is no obivous dependence of burst occurrence on the up-down orientation of the detector. This result appears to be consistent with our prior conclusion that the region of acceleration or precipitation control is located in close proximity to the rocket. On the other hand, a statistical analysis shows that the burst occurred with a definite east-west preference. Even though we are unable to determine whether the preference was from the west or the east, we do know that the bursts occurred preferentially from the same direction from which the larger fluxes in the pitch angle asymmetry arrived.

The data from the ac electric field experiment showed the same large amplitude signals recurring at the spin frequency seen on the April 25, 1968 flight. Our previous interpretation of these signals was that they were indicative of a vehicle interaction with the environment and that they were not characteristic of naturally occurring fluctuating electric fields. Hence we have not devoted a significant effort to the interpretation of results from this experiment. One very interesting result, however, is that each detected particle burst event is always accompanied by the large amplitude ac experiment signal; the converse correlation is not valid. We assume that this large ac signal is caused by amplifier overload produced by a transient imbalance in the potential of the antenna elements. Such a transient potential imbalance could easily be caused by the described impulsive change in the energetic particle precipitation associated with the burst events.

The response of the dc channel to a steady state electric field and the induced v x B/c electric field should be a sine wave at the spin frequency. The launch azimuth was ∿140°; thus the v x B/c field should have been ∿10 millivolts m^{-1}. This expected sinusoidal signal was observed throughout the first flight [*Bernstein et al.*, 1969c]. However, there was no evidence whatsoever for such a signal on the present flight. Consequently we conclude that this channel did not operate satisfactorily probably because of a malfunction in the deployment of the antenna elements.

The results of our two flights into auroral breakup events, carried out on 25 April 1968 and 17 April 1969, have shown striking consistency and are summarized below:

1. Large (10^9 cm^{-2} sec^{-1}), low energy (1 kev) hydrogen fluxes were precipitated during the breakup and post breakup phase. The energy precipitation in the hydrogen component was comparable to that in the electrons.

2. The measured ratio, H^+/H^o, was consistent with that expected when charge exchange and stripping equilibrium is attained.

3. The data from the first flight were indicative of non-Poisson distribution in the times of arrival of hydrogen atoms at the detectors. Because the second flight employed fixed energy analyzers, which operated continuously, the burst nature of the hydrogen precipitation was clearly seen in the second flight. These hydrogen enhancements were associated with equally abrupt decreases in the precipitated electrons. These proton bursts appeared to occur with equal probability from above and below the rocket location, but had an east-west preferential direction of occurrence.

4. The spatial extents of the hydrogen forms were much less than predicted by *Davidson* [1965] for the altitudes at which the observations were made despite the fact that the proton pitch angle distribution was peaked near 90°. This pitch angle distribution was not always symmetrical about 90°, but at times showed a pronounced east-west asymmetry.

5. Measurement of the dispersion in arrival times of different energy hydrogen atoms or protons can yield valuable information on either acceleration or precipitation processes if it is assumed that particles of all energies are acted upon in the same fashion. The data from the first flight indicated that these processes were active within a distance of <1000 km from the rocket. Because of the much better instrumentation on the second flight, this maximum distance from the rocket was found to be ≤ 50 km. The burst acceleration or precipitation processes therefore were low altitude phenomena.

6. Observations indicated that both the electron and proton energy spectra remain relatively unchanged from the "steady state" condition during periods of burst activity. Because of the observed power law dependence of both energy spectra, the unchanged character of the energy spectrum was not consistent with the idea of acceleration by a local unidirectional electric field. Similar acceleration by a unidirectional electric field should result in a larger enhancement factor than decrement factor because of the power law character of the energy spectra; the inverse was observed.

3. Discussion of Results from the Tomahawk Flight

The idea that particle acceleration or precipitation control occurs at altitudes less than a few thousand kilometers is not new. *Evans* [1967], and *Mozer and Bruston* [1966] and *Albert* [1969] have reached this conclusion based upon observed electron velocity dispersions and proton and electron pitch angle distributions respectively. In fact, only one study, based upon observed electron velocity dispersions, has placed the location of this region at large distances, possibly the equator [*Bryant et al.*, 1969]. Because of our greater temporal resolution which arose primarily because of our measurements on the lower velocity protons and hydrogen, we have been able to place the location of a region of acceleration or control, in the lower ionosphere.

Evans [1967] has proposed that a beam-plasma instability produced by the interaction of the relatively monoenergetic component of the precipitated electrons with the ionosphere could explain his observations. As a result of this instability, some fraction of the precipitated electrons or ionospheric electrons are accelerated to substantially higher energies. The observed periodic behavior in these higher energy electrons is attributed to the marginal stability of the plasma configuration and the recurrent quenching of the instability. Evans has not performed any measurements of proton precipitation during such periods of activity. Clearly from our observations, the required process is not limited to electrons alone, but must also severely modify the precipitated hydrogen energy and flux distributions. Also, there is no evidence whatsoever for a significant monoenergetic precipitated electron component at any time during the second flight, and therefore the occurrence of a beam-plasma instability seems unlikely. For these reasons, we do not believe that the mechanism proposed by Evans is applicable to the present experimental results.

Mozer and also Albert have invoked the existence of a steady state electric field parallel to the geomagnetic field to explain their pitch angle observations. The most recent theoretical treatment for the generation of such an electric field is by *Kennel and Kindel* [1970]. They suggest that because of an initial preponderance of electron precipitation, a charge separation electric field is created along the lines of force in the upper ionosphere. Because of this field, return currents will flow upward from the 100 km region in order to cancel the charge imbalance. They calculate that this return current flow will become unstable at altitudes above 1000 km based on typical electron precipitated fluxes, and ionospheric electron temperatures and densities. The resultant wave-particle interactions will inhibit the required current flow and therefore result in an anomalous or collisionless resistivity. Because of this resistivity a steady state electric field can be maintained parallel to B in the essentially collisionless upper ionosphere. This analysis does not appear to be applicable to the present data for several reasons: (1) The experimental results are inconsistent with the existence of a unidirectional electric field. (2) Their present instability criteria place the region of anomalous resistivity at altitudes above 1000 km which is inconsistent with the observed placement of the region of acceleration or precipitation control at much lower altitudes. (3) Their theory does not predict or consider the observed transient or burst nature of the precipitation. (4) It is difficult to understand how anomalous resistivity can lead to the very localized observed region of precipitation of control. (5) Their proposed electric field could lead to a "runaway" acceleration of some fraction of the higher atomic number ion constituents of the ionosphere; there have been no observations of the occurrence of such a runaway acceleration. (6) The initial condition of excess electron flux at the 1000 km level is probably not met.

It should be noted that a significant separation of charge can be produced in the altitude range 100-300 km for equal fluxes of hydrogen and electrons in the 1-10 kev energy range if it is assumed that all the precipitated hydrogen was in the proton state at the top of the atmosphere. The incident proton flux will be 90% neutralized between 200 and 300 km by charge exchange whereas the electrons continue to the 100 km region. The consequences of this low altitude charge separation remain to be considered, but they could influence both the observed limited proton spreading and the penetration of protons to low altitudes. However, the results from our recent solar eclipse Javelin flight [*Wax and Bernstein*, 1970b] suggest that the precipitated hydrogen flux may be in the neutral rather than the proton state at the top of the atmosphere. In this case, the charge separation pattern would be similar to that suggested by Kennel and Kindel for predominant electron precipitation, but with the two distinct regions of negative charge; one at 200-300 km where the hydrogen is stripped and another at 100 km where the electrons are stopped.

On the first flight, the rocket fortuitously passed through a form boundary. Both the measurements of neutral hydrogen and electrons >2 kev gave the same location of the form boundary; the electrons <2 kev extended several kilometers poleward. This sharply defined hydrogen boundary was not in agreement with *Davidson's* [1965] predicted spreading of a precipitated proton beam because of the repeated charge exchange and stripping reactions which occur during the transit of hydrogen through the atmosphere. Because the hydrogen and proton detectors were all aligned parallel to the spin axis, little meaningful information about the hydrogen pitch angle distribution was obtained on the first flight. Therefore, we propose that the sharp hydrogen boundary could be explained by either an incident hydrogen pitch angle distribution more sharply peaked parallel to the magnetic field or a much lower density of the upper atmosphere than had been assumed by Davidson. Unfortunately a form boundary was not observed on the second flight; however, the precipitated hydrogen pitch angle distribution always appeared peaked nearly perpendicular rather than parallel to the magnetic field. These results are in agreement with measurements reported by *Chase* [1970] during several auroral breakup events. If we assume that this anisotropy is characteristic of hydrogen precipitation during the breakup, and that it was also present during the first flight, it seems likely that the observed hydrogen boundary indicates the reduced density of the upper atmosphere. This conclusion is consistent with the observed penetration of low energy (1-10 kev) hydrogen to the 100 km altitude range. There is a third, unexplored possibility which might make use of ac-electric and magnetic fields in order to both energize and confine the proton beam.

The observed variability in the pitch angle distribution and more particularly in the apparent east-west asymmetry is consistent with concept that the lower ionosphere is an extremely active medium. The imposition of the east-west asymmetry from a source at high altitudes appears unlikely; a low altitude modification of the precipitation by local fluctuating electric and magnetic is more reasonable. Clearly the entire area of low altitude auroral phenomena requires further experimental and theoretical study.

B. Auroral Javelin Proton and Neutral Spectrometer

Results

These instruments were flown on rockets 8:55 UE and 8:56 UE from Ft. Churchill. Their design was identical to the one flown on the Tomahawk except for a different high voltage sweep. In this case the sweep cycled once a second.

The first rocket was launched into weak activity. There was a boom deployment problem with another experiment which caused the rocket to tumble; the data are therefore not complete because of many telemetry drop-outs. There was an apparent malfunction of our spectrometers since almost all the recorded counts occured simultaneously in both the proton and neutral counting channels; the instantaneous rates in each channel were thus equal. We believe the data are probably the sum of the counting rates for both channels because another experiment had a similar malfunction on the second flight. There are two possible causes for this summing of counts. The first is that there was cross talk between our discriminators; the second is that there was a malfunction of the Berkeley pulse code modulator unit. The count rates were so low throughout the flight that no data concerning burst phenomena or atmospheric attenuation of the hydrogen beam can be obtained. Because of the large neutral efficiency factor, the major portion of the observed counts were probably protons. One concludes that the proton flux at kilovolt energies was on the order of 10^3 to 10^4 throughout most of the flight. This is consistent with the low proton fluxes observed by other instruments on the rocket.

The second rocket was launched into an active auroral breakup condition at Ft. Churchill. Fifteen seconds after high voltage turn on, there was a sudden drop in the observed counting rate and until the rocket reached the 200 km level on the downleg of the flight, there are practically no counts observed by either channel, even though the other instrument on the rocket showed extremely large proton fluxes above 60 kev. We believe that the channeltron high voltage supply did not function properly during that portion of the flight. In the periods where data exist, the neutral hydrogen flux was $\sim 10^7$ cm^{-2} sec^{-1} and the proton fluxes were $\sim 10^6$ cm^{-2} sec^{-1} which appears to be consistent with what was observed by other instruments at that time. However, the rocket was no longer within the active auroral forms. There were peaks in the hydrogen spectra, but it should be remembered that the energy sweep rate was only once per second so that it is impossible to say if these peaks result from the energy distribution or from flux increases. The data would be consistent with either interpretation. The spectra were soft showing a two decade decrease in the neutral hydrogen flux between 1 and 7 kev. The counting rates were not high enough to distinguish if burst structure was present.

Neither instrument was able to make a measurement of the neutral to proton ratio as a function of altitude or to observe bursts. Thus, we were unable to make the observations we wished to have made.

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FIGURE CAPTIONS

Table 1. Characteristics of the Instruments Flown on the Auroral Tomahawk Flight.

Figure 1. Typical differential energy spectra of electrons and neutral hydrogen observed on the auroral Tomahawk. The fluxes have not been corrected to the top of the atmosphere.

Figure 2. Display of auroral impulsive precipitation events in 5000 ev radial and axial protons and 200 and 6000 ev electrons.

Figure 3. A proton burst from Figure 2 at 5000 ev in the radial and axial directions shown on an expanded time scale.

Figure 4. Response of the 5000 ev radial proton detector as a function of observed pitch angle showing a strong east-west asymmetry which decreases with time.

Figure 5. Time of occurrence of impulsive precipitation events as a function of pitch angle. Points are the events. The soild lines represent the range of pitch angles covered at a given time.

TABLE 1

Instrument	Look Direction	Energy Range	Geometrical Factor (cm^2 str)	Efficiency	Typical Count Rate (Counts per sec)
Total Hydrogen Detector	Axial	Integral Flux 0.5-10 kev	2.2×10^{-2}	7×10^{-3} Energy independent	7.5×10^{3}
Neutral Hydrogen Energy Spectrometer	Axial	5 Channels 0.5-9 kev	4.60×10^{-3}	eff = $1.3 \times 10^{-3} E^{1.8}$ E = energy in kev	20
Proton Energy Spectrometer	Axial	5 Channels 0.3-8 kev	4.60×10^{-3}	≈1	1.3×10^{3}
Electron Energy Spectrometer	Axial	5 Channels 0.2-6 kev	2.51×10^{-3}	≈1	4×10^{4}
0° Proton Detector	Axial	Fixed Energy 5 kev	2.74×10^{-2}	≈1	3×10^{4}
90° Proton Detector	Radial	Fixed Energy 5 kev	2.74×10^{-2}	≈1	6×10^{4}

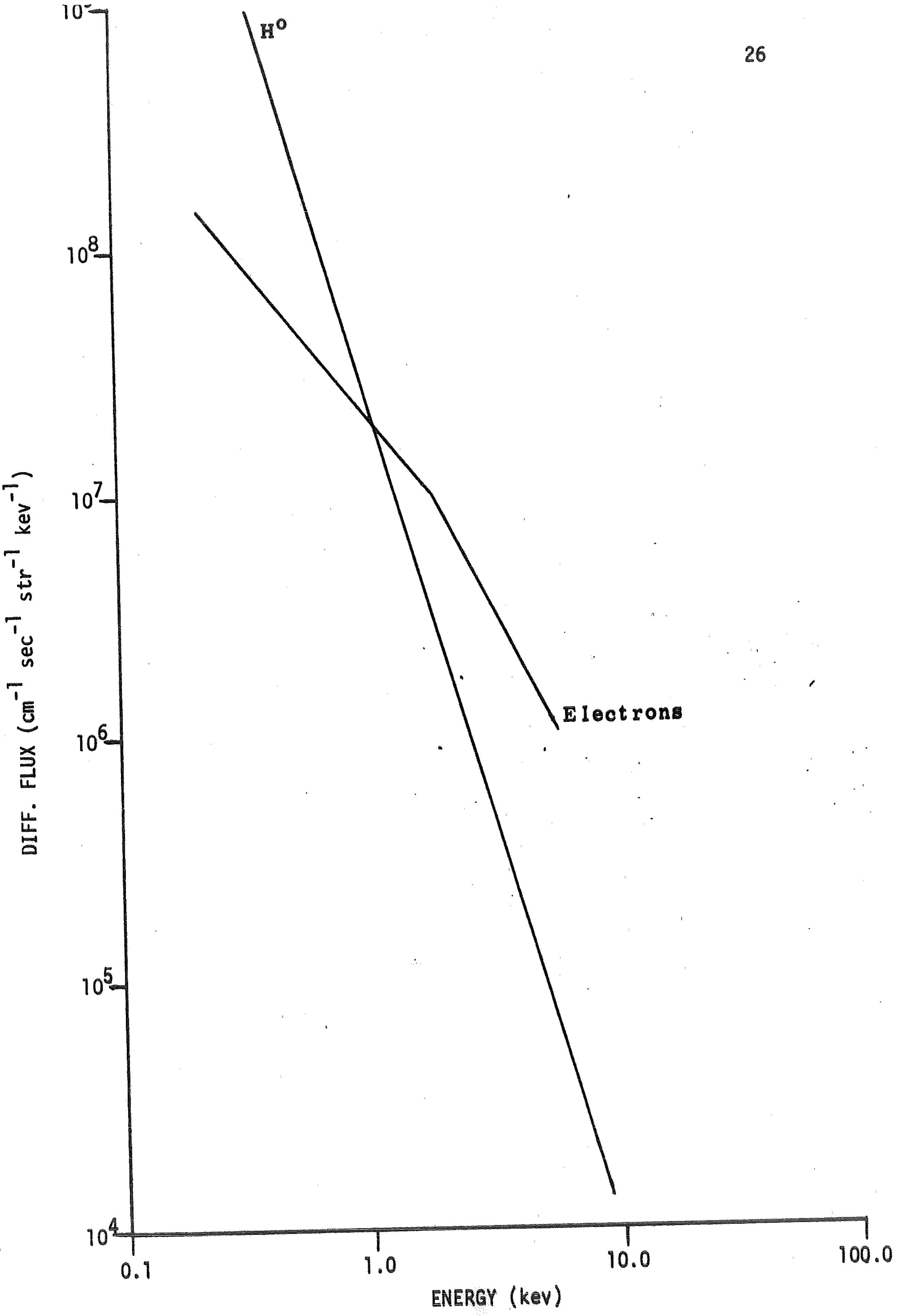
10
10^8
10^7
10^6
10^5
10^4
DIFF. FLUX (cm^{-1} sec^{-1} str^{-1} kev^{-1})
H^o
Electrons
0.1
1.0
10.0
100.0
ENERGY (kev)

Figure 1.

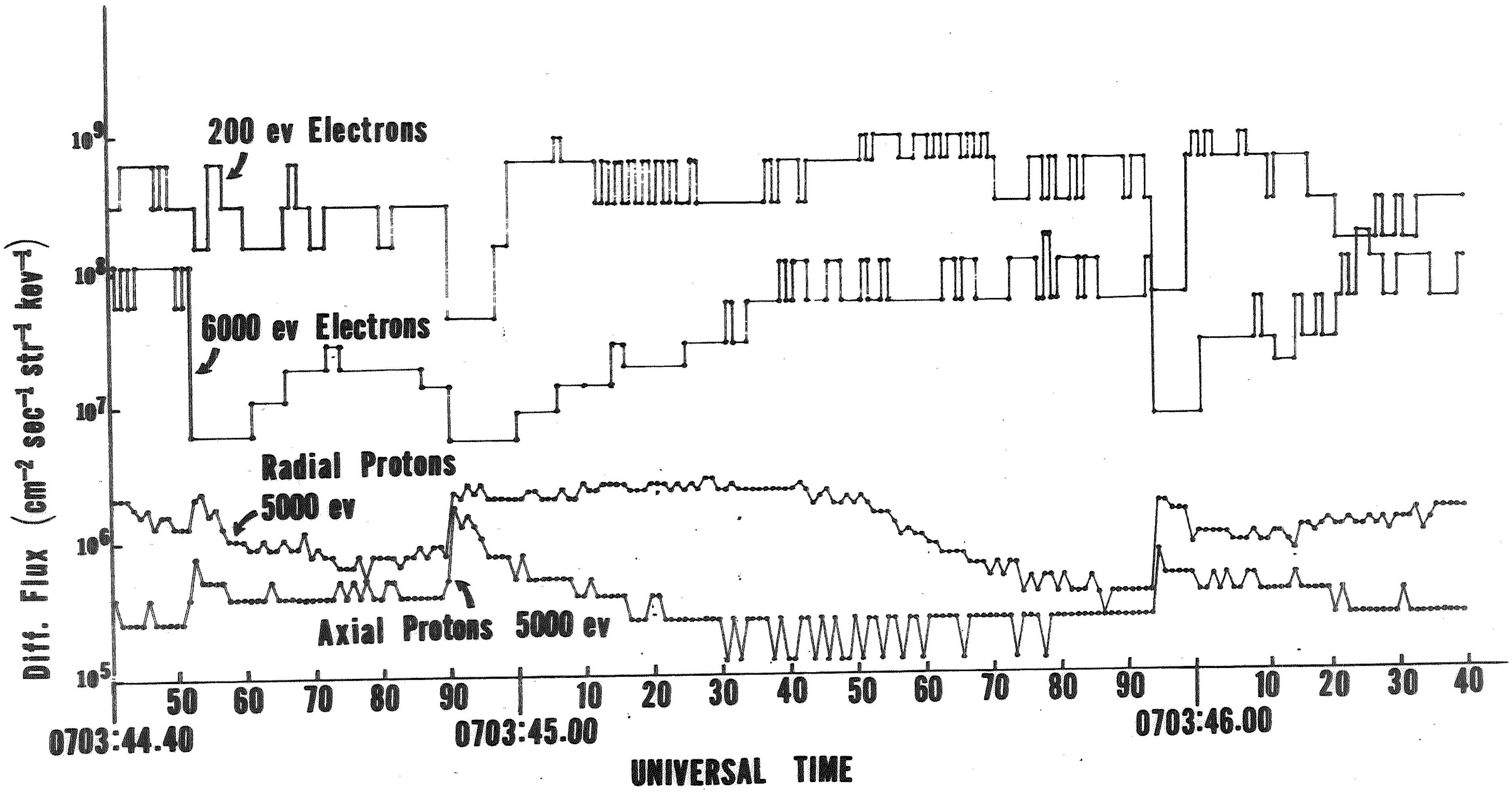
200 ev Electrons
6000 ev Electrons
Radial Protons
5000 ev
Axial Protons 5000 ev
Diff. Flux (cm^{-2} sec^{-1} str^{-1} kev^{-1})
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
50
60
70
80
90
10
20
30
40
50
60
70
80
90
10
20
30
40
0703:44.40
0703:45.00
0703:46.00
UNIVERSAL TIME

Figure 2.

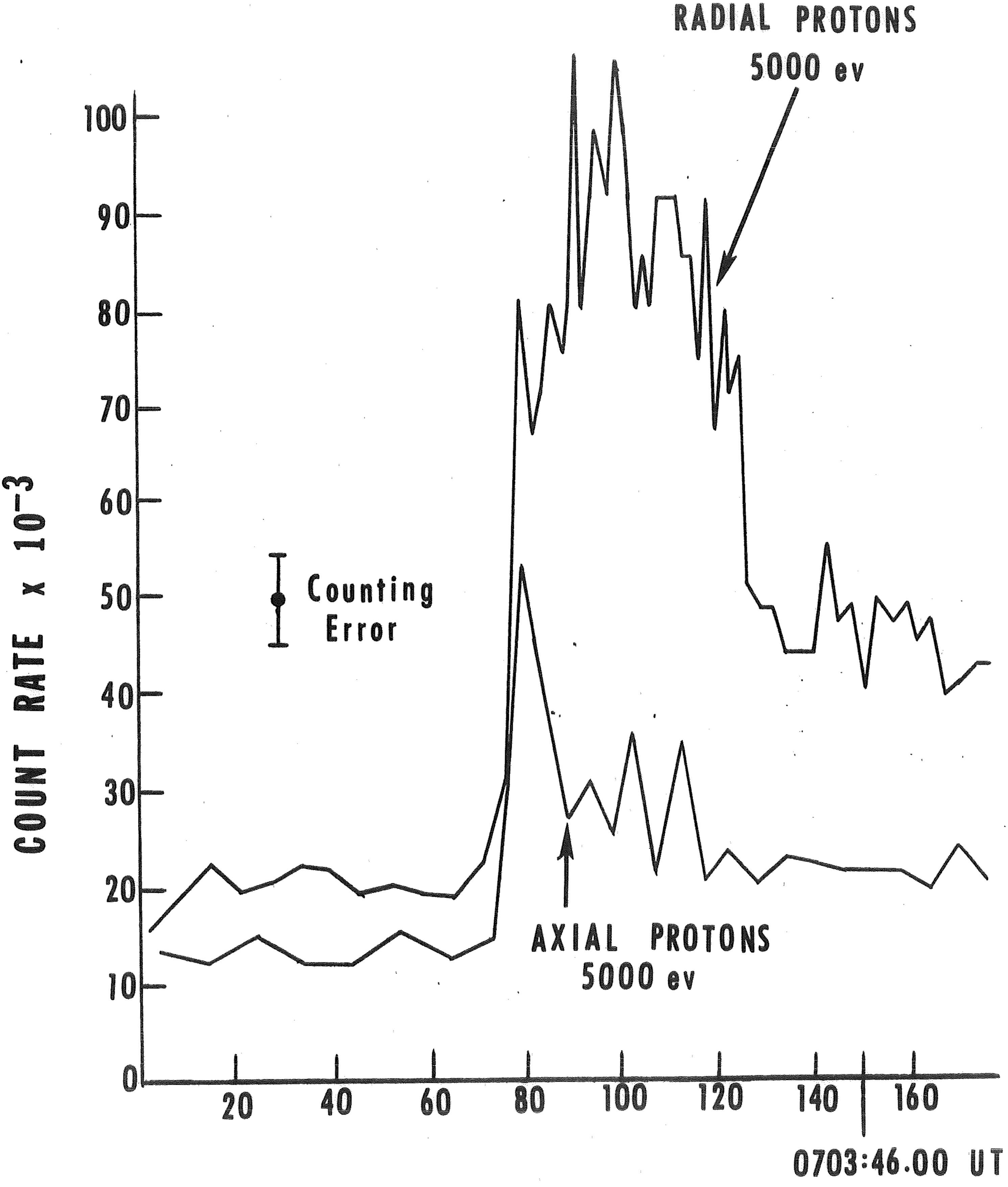
RADIAL PROTONS
5000 ev
COUNT RATE x 10^{-3}
100
90
80
70
60
50
40
30
20
10
0
Counting Error
AXIAL PROTONS
5000 ev
20
40
60
80
100
120
140
160
0703:46.00 UT
TIME (msec)

Figure 3.

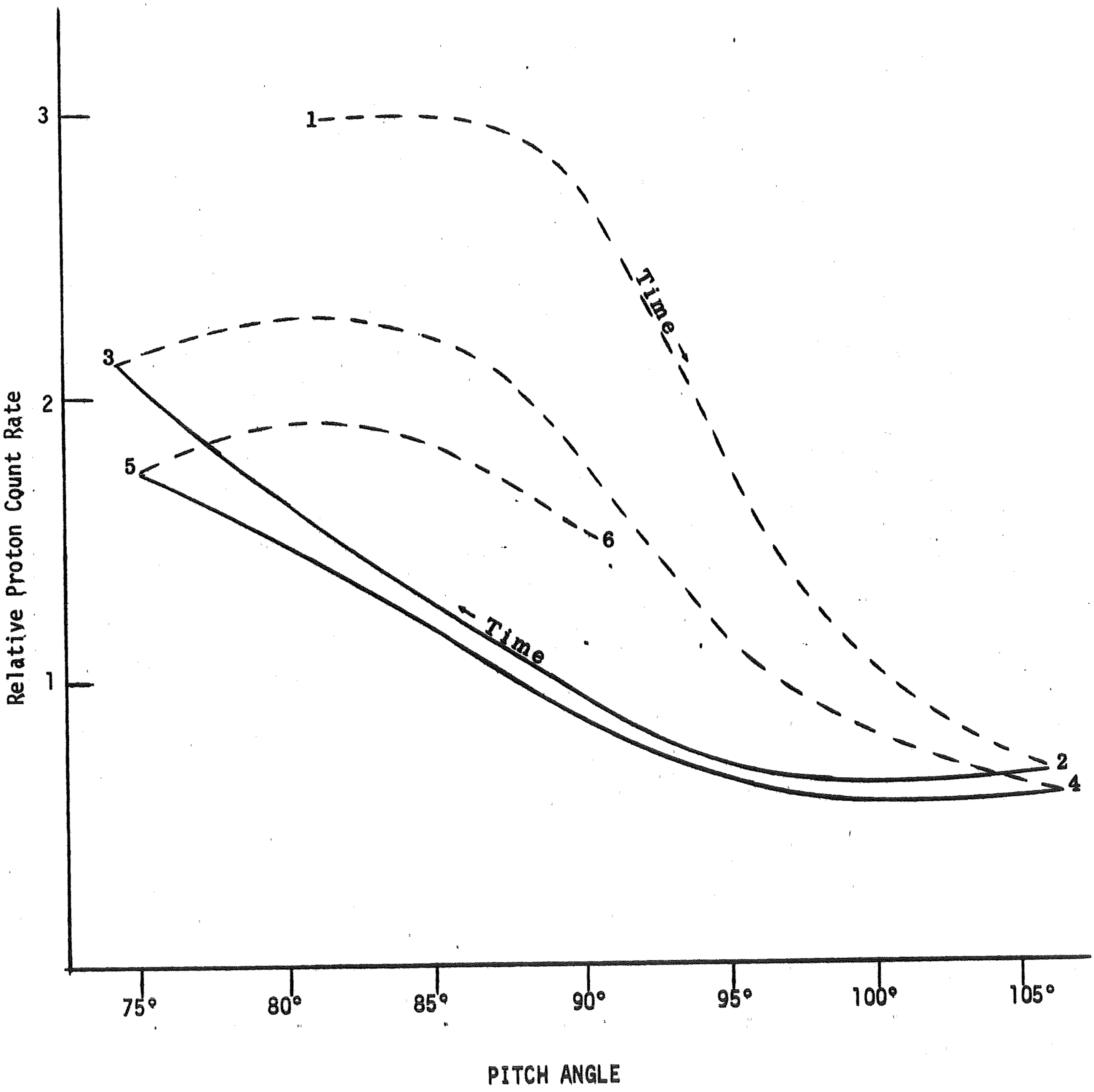
Relative Proton Count Rate
3
2
1
1
2
3
4
5
6
Time
Time
75°
80°
85°
90°
95°
100°
105°
PITCH ANGLE

Figure 4.

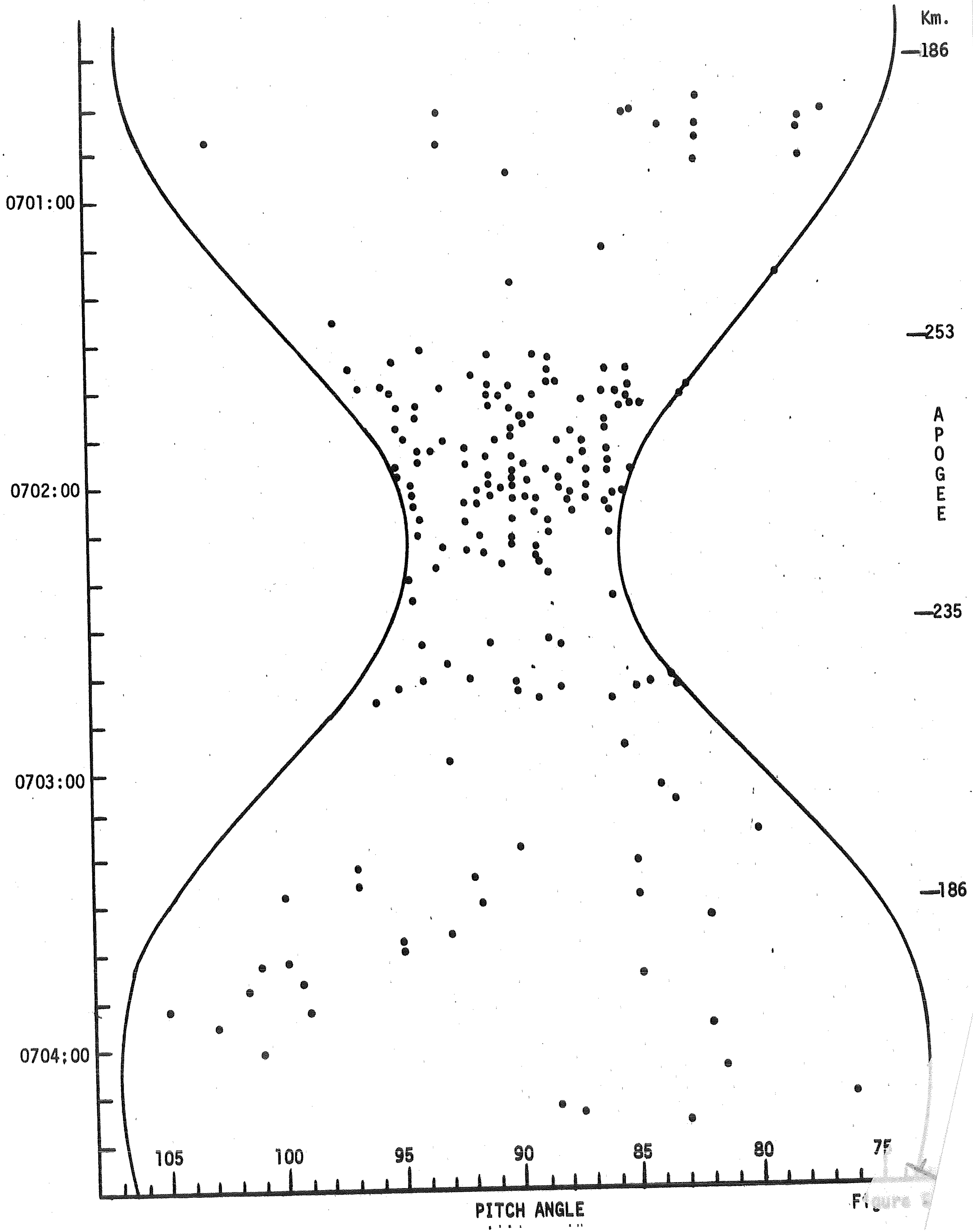
Km.
186
253
APOGEE
235
186
0701:00
0702:00
0703:00
0704:00
105
100
95
90
85
80
75
PITCH ANGLE

Figure 9