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GODDARD SPACE FLIGHT CENTER
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ABSTRACT

Simultaneous observations of positive ion composition, vlf earth to satellite transmission, and whistlers, have been obtained from the OGO-2 satellite during October, 1965 in a polar, dawn-dusk orbit. As the satellite moves poleward above about 55° invariant latitude, sudden depletions of the light ion components of the topside ionosphere are observed, wherein the concentrations of H^+ and He^+ decrease by as much as an order of magnitude within 3°Λ. The light ion trough correlates with similar rapid reductions in the propagation of both man-made and natural vlf signals received at the satellite, where signal intensities are observed to decrease by as much as 20 db, and whistler rates decrease abruptly within 3°Λ. Poleward of the trough, the depleted light ion distributions are characterized by rapid fluctuations in concentration which appear to correlate in some cases with significant enhancements in the vlf noise level. The combined evidence of the light ion depletion and vlf cutoff further identifies the

plasmapause as the often abrupt boundary of the plasmasphere. The abruptness of the light ion trough suggests the possibility that the mechanism responsible for the depletion results, under certain conditions, in a sharply defined heating and upward expansion of the lower atmosphere. Limited evidence of vlf absorption as well as abrupt increases in neutral density near the trough zone appear consistent with this possibility.

CONTENTS

ION DEPLETION IN THE HIGH LATITUDE EXOSPHERE; SIMULTANEOUS OGO-2 OBSERVATIONS OF THE LIGHT ION TROUGH AND THE VLF CUTOFF

INTRODUCTION

Pronounced latitudinal variation in the composition of the topside ionosphere has been identified in the ion spectrometer data from the Orbiting Geophysical Observatory (OGO) 2 and 4 satellites [Taylor et al., 1968]. In particular, abrupt high latitude depletions or troughs in H^+ and He^+ are observed near 60°Λ (L=4), where the light ion concentrations decrease by as much as an order of magnitude within 3 degrees of latitude. These results, with other data obtained over a wide range of locations and conditions from direct measurement satellites, topside sounders, and vlf studies, indicate a general pattern of the upper ionosphere in which the mean ion mass increases from the equator, where H^+ becomes significant, toward the poles, where O^+ tends to dominate the composition. Although this pattern is not yet complete in terms of local time, altitude, and seasonal effects, the results of the light ion measurements also indicate a relatively strong, uniform distribution of ionization at low and mid-latitudes, followed by significantly reduced and very irregular ion distributions poleward of the light ion trough zone.

It thus appears most likely, as suggested by Carpenter [1966] and Angerami and Carpenter [1966], that the outer ionosphere or plasmasphere is contained

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for which both ion and vlf data are available from OGO-2 and to show that in these cases the light ion trough, the whistler cutoff, and the vlf propagation cutoff do indeed occur nearly simultaneously. In addition, irregular features of the poleward distributions of both the ions and the vlf noise are revealed, further describing the polar ionosphere as a region characterized by rapid fluctuations in composition and particle concentration.

THE EXPERIMENTS

The vlf and ion composition data were obtained from companion experiments on OGO-2, launched on October 14, 1965 into a near polar orbit with an apogee of 1525 km and a perigee of 415 km (Figure 1). The data for this study were obtained during the first ten days of satellite operation, when successful performance of the attitude control system permitted acquisition of most reliable ion data. During this period the orbit maintained a dawn-dusk local time orientation.

The ion composition experiment consisted of a Bennett rf spectrometer tuned to detect thermal positive ions in the mass range 1–45 amu, at a rate of once every 25.6 seconds, providing a resolution between measurements of the same ion of about 1.5 degrees of latitude. Throughout the altitude range the primary ions detected were O^+, H^+, He^+, and N^+. The measured individual ion currents were converted to equivalent ion concentrations and from these data the values for the corresponding parameters mean ion mass, M_i, and total ion concentration, N_i, were calculated. Further details of the experiment operation and the composition results are reported elesewhere [Taylor et al., 1968].

The vlf experiment employed a loop antenna and included a 0.3 - 12.5 kHz broadband receiver and a tunable phase tracking receiver with 50 Hz bandwidth. Further details of the vlf experiment are presented elsewhere [Ficklin et al., 1965; Heyborne, 1966].

EXPERIMENTAL RESULTS

High Latitude Light Ion Trough

A pronounced feature of the OGO-2 dawn-dusk ion composition results is the abrupt depletion, or trough, observed nearly simultaneously in the $n(H^+)$ and $n(He^+)$ distributions as the satellite passed poleward near 60°Λ (Figure 2). Although a detailed description of the OGO-2 ion data are given elsewhere, emphasis of several details of the extreme latitudinal variation observed in the topside composition enhances consideration of the correlations studied here.

First, it was observed that the ion trough was a persistent feature of the dawn-dusk high latitude topside ionosphere, occurring over a wide range of magnetic activity (Kp = 0-4). The trough was detected repeatedly above 500 km in both the northern and southern hemispheres, with minimum H^+ and He^+ concentrations occurring near 60°Λ. The trough interval is often defined by a rapid decrease of as much as an order of magnitude or more in both $n(H^+)$ and $n(He^+)$ within three to five degrees of latitude. On the basis of limited statistics, there is also evidence of an inverse correlation between Kp and Λ, with the trough minimum decreasing in concentration and moving to lower latitudes with increased Kp. Significantly, the ion trough is also observed in the OGO-4 ion composition data. Although the character of the trough has not yet been fully examined with respect to local time and seasonal variability, characteristic trough structure has been observed repeatedly between 600-900 km, and at widely different local times, including midnight and noon.

Second, the trough is identified as a light ion trough due to the fact that the distributions of the other primary topside ions, O^+ and N^+, do not regularly exhibit significant trough structure, particularly during periods of low magnetic activity ($Kp \leq 2$). With increased activity ($Kp = 3$-4) however, depletions in $n(O^+)$ and $n(N^+)$ of as much as a factor of three in concentration have been observed, at the position of the light ion minima.

Poleward of the light ion trough, the reduced concentrations of H^+ and He^+ usually exhibit considerable fine structure as shown in Figure 2. In the same region, distributions of N^+ and O^+, which generally increase in concentration toward the poles, also reveal considerable fluctuations. Although the variation among the four ions is sometimes not clearly related, variations are frequently observed in which the concentrations move together forming mini peaks and troughs in which the concentration of each of the ions may change by as much as a factor of two to five.

Latitudinal Cutoff Effects in Whistlers and vlf Noise

The whistler cutoff appears as an abrupt decrease in the rate of whistlers propagating on magnetospheric paths from the conjugate hemisphere to the satellite [Carpenter et al., 1968]. Details of the propagation paths are not yet well known; both ducted and nonducted signals are probably involved. The cutoff in fixed frequency transmissions usually involves upgoing (fractional-hop) signals when the satellite is in the hemisphere of the transmitter. When in the hemisphere conjugate to the transmitter, the satellite observes cutoff effects in what is probably a mixture of fractional-hop and magnetospheric-path propagation. (A detailed study of fixed-frequency propagation to OGO-4 is in progress.)

Simultaneous Ion Trough and vlf Cutoff Events

Within the limited span of the OGO-2 control mode data, there occurred numerous examples, near both dawn and dusk, of a near simultaneous occurrence of the light ion trough and cutoff effects in fixed-frequency and/or broadband vlf data. Frequently, due to experiment scheduling, correlations were limited to only two of the three types of data, e.g. ions and broadband vlf, although such events substantiate the persistent nature of the correlation. Accordingly, we have restricted the events to be discussed to two representative cases for which the three sets of simultaneous results of composition, broadband vlf, and fixed-frequency vlf transmission are available. These events are illustrated in Figures 3, 4, 6 and 7. The geographic relationship between the subsatellite track and the position of the NAA transmitter is shown in Figure 5.

Details of the October 23, 1965 Event

Simultaneous evidence of (1) a rapid depletion of light ions, (2) pronounced cutoff effects in broadband vlf and (3) a sharp cutoff in the field strength of NAA transmissions at 17.8 kHz is given in Figures 3 and 4. Figure 3 shows the variations with time (top) and invariant latitude (bottom) of satellite altitude, mean ion mass (M_i), ion concentration (N_i), light ion concentrations (H^+ and He^+), and NAA field strength. (For NAA, the solid line indicates identifiable Morse code; the dashed line, the prevailing vlf noise level in a 50-Hz band at the NAA frequency.) The ion distributions are fairly typical of results obtained in the northern hemisphere at dawn during periods of moderate magnetic disturbance (Kp = 3-4). In Figure 3, at latitudes below about 55°Λ, the concentrations of hydrogen and helium are relatively strong and regular, and the amplitude of upgoing NAA signals is steady at about $10^{-4}\gamma$. Broadband whistler and noise activity at latitudes below about 57°Λ is shown in Figure 4, upper right, and in an expanded segment on panel B of Figure 4. Below 57°Λ the whistler rate is relatively high, with more than ten well defined events per minute. (From 1445:02 to 1445:25 (panel B) the whistlers are relatively faint. Such a brief period of low whistler intensity is frequently observed just equatorward of the whistler cutoff.)

Referring again to Figure 3, there is a sharp decrease in light ion concentrations above 55°Λ and a resulting trough, with minimum concentrations near 1445 (57°Λ, L = 3.4). The trough is seen essentially simultaneously in both $n(H^+)$ and $n(He^+)$. Above about 55°Λ the field strength of NAA also decreases abruptly, falling by more than 20 db within 3°Λ.

As OGO-2 moved equatorward on this pass, whistlers propagating to the satellite from the conjugate region began to appear abruptly at about 57°Λ. This is shown in panel B, Figure 4, where whistler activity commences suddenly at 1444:57 (arrow in upper margin), and then decays for a short period as noted above. Just prior to the appearance of whistlers there is intense irregular vlf noise activity above 6 kHz. Complex noise effects of this kind have been observed on Alouette vlf records of plasmapause crossings [Carpenter et al., 1968], although a detailed description of such effects has not yet been made.

Poleward of the trough, the reduced light ion distributions often exhibit considerable irregularity, as shown in Figures 2 and 3. The poleward boundary of the trough is often marked by rapidly forming and irregularly spaced peaks which reach concentrations typically three to five times the minimum concentrations of $n(H^+)$ and $n(He^+)$ observed in the trough. In the same interval, the broadband vlf exhibits a variety of noise forms, including (1) irregular noises above ~5 kHz between 1444 and 1445, (2) chorus forms (~0.3 - 3 kHz) between 1442 and 1447 and (3) auroral hiss (<5 kHz) between 1439 and 1443. Panel C of Figure 4 shows some details below 10 kHz of the auroral hiss that appears as a peak in the NAA channel of Figure 3.

Panel D of Figure 4 shows detail of hiss activity and some chorus forms near 66°Λ, when there occurred a relatively abrupt transition from predominantly hiss to predominantly chorus activity. While the high levels of vlf noise activity between about 1439 and 1445 generally coincide with the rather broad recovery in

$n(H^+)$ and $n(He^+)$, this event contains only limited fine structure in the ion data and thus affords little opportunity for relating ion fluctuation and vlf noise structure. Note that the spatial resolution of the consecutive ion measurements is limited to about 1.5°, and thus more rapid fluctuations in the ion distributions may be missed. Recent higher resolution ion measurements from OGO-4 do in fact reveal such variability.

The light ion trough of Figure 3 is somewhat less pronounced than the higher altitude example shown in Figure 2. In Figure 3, the trough region is traversed at considerably lower altitudes (about 500 km, compared to about 1000 km in Figure 2) and the relative intensity of the trough is somewhat reduced by the superimposed tendency for $n(H^+)$ and $n(He^+)$ to decrease with decreasing altitude as the satellite moves equatorward. Below about 500-600 km the light ion distributions are believed to be controlled largely by chemical processes and are observed to exhibit negative scale heights below 500-600 km, at low and mid-latitudes [Taylor et al., 1968; Brinton et al., 1969]. Nevertheless, the altitude-latitude variation is comparatively slow and regular, and in no way masks the marked light ion depletion. In the trough interval the concentrations of the heavier ions O^+ and N^+ (not shown) are not significantly reduced, and thus the total ion concentration, N_i, exhibits only a minor decrease within the interval. Further, since $n(O^+)$ dominates in this altitude-latitude range, the mean ion mass, M_i, follows a level near 16 amu and does not reflect the influence of the light ion trough.

Details of the October 22, 1965 Event

Characteristics of a southern hemisphere ion and vlf event obtained on October 22, 1965 are shown in Figures 6 and 7. As in the northern hemisphere, the plasmasphere is identified by the strong, regular ion distributions below about 55°Λ and by the presence of whistlers and a steady level of detectable Morse code transmission from NAA. Abruptly at about 1127 (57.5°Λ, L=3.5) both the light ion concentrations and the NAA field strength begin to decrease significantly. Figure 7, upper left, shows whistler activity at latitudes below ~58°Λ to be relatively steady at the rate of four or more per minute. The activity terminates near 58°Λ, with the last well defined whistler at about 1127:14 (Figure 7B, arrow in upper margin). At this time $n(H^+)$ and $n(He^+)$ (cf. Figure 6) have decreased by about a factor of ten, while the NAA field strength has decreased by about 10 db.

Intense banded vlf noise and discrete rising forms in the range 6-8 kHz appear just poleward of the whistler cutoff. The banded form is a common type of plasmapause-associated noise, and is similar to noise frequently detected during plasmapause crossings near the magnetic equator by OGO-1 and OGO-3 [Dunckel and Helliwell, 1969].

Poleward of the light ion trough, vlf hiss is observed beginning weakly near 1135 and extending to 1136 (Figure 7C). In the same interval, vlf noise in the NAA channel increases and both $n(H^+)$ and $n(He^+)$ increase to form auroral peaks near 1136 (77°Λ, L = 20), coinciding with the most intense portion of the broadband hiss activity.

The relative overall constancy of N_i, as well as the increase in M_i in the trough interval in Figure 6 reflects the general tendancy for $n(O^+)$ to increase toward the poles, as $n(H^+)$ decreases, and also illustrates in this case the absence of a trough structure in $n(O^+)$. The variability in N_i observed between 1135 and 1139 results from fluctuations in the auroral zone distribution of the dominant ion O^+.

Plasmapause Position

The approximate latitude of plasmapause crossing for both cases illustrated was 57°Λ or $L \sim 3.7$. The southern hemisphere case of October 22, 1965 near 1130 UT (dawn) agrees well in latitude with northern hemisphere crossings about 30 minutes earlier and about one hour later (also dawn), in both of which ion and vlf data were compared. Magnetospheric substorm activity (from AE indices compiled by D. Fairfield) was at a low level on October 21 and on October 22 until ~0800 UT, at which time a two hour surge of activity began. From current whistler studies the time and duration of the increase should have been sufficient to cause a decrease in plasmapause radius to a value of the order observed. The estimate of $L \sim 3.7$ for plasmapause position on October 23, ~1500 UT, again near the dawn meridian, is consistent with the moderate but relatively steady level of substorm activity persisting through the latter part of the 22nd and through the 23rd.

DISCUSSION

High Latitude Ion Depletion

The phenomenon of rapid high latitude depletion of ionization has been the subject of numerous studies, beginning with the observations of the F-region 'main trough' in N_e [Muldrew, 1965], and including similar results on trough-like structure by Sharp [1966], Thomas et al. [1966], and Rycroft and Thomas [1968]. Significantly, these results obtained over a wide range of local times all refer to depletions in N_e, whereas the ion composition results [Taylor et al., 1968] reveal that while moderate trough structure is seen in N_i (and presumably N_e), the predominant characteristic is a pronounced trough in $n(H^+)$ and $n(He^+)$ at least in the dawn-dusk region. Considering the limited evidence from the OGO data that the N_i trough deepens with increased magnetic disturbance, it is of course possible that under different conditions, a pronounced trough might be observed throughout the composition. Thus, during periods of elevated solar activity, the N_i-N_e trough may well be observed as a more persistent phenomenon. Even during periods of low magnetic activity (Kp = 0-2), however, the light ion trough has been observed repeatedly in the high latitude ionosphere. This evidence, coupled with the observations of a close relationship between the ion trough and the vlf cutoff during periods of moderate magnetic activity, leads to the assumption that the light ion trough and the whistler cutoff are both manifestations of the plasmapause.

A most important characteristic, common to many of the ion and vlf results, and one which influences consideration of possible mechanisms, is the abruptness frequently observed in both the ion depletion and the vlf cutoff. It does not appear likely for example, that a relatively slowly varying zenith angle - ionization mechanism is responsible, particularly in view of the observed increase in the concentrations of the heavier ions O^+ and N^+ with latitude poleward of the trough—cutoff zone. Similarly, while recent studies of the interdependence of the topside electron temperature and ion composition [Mayr et al., 1968; Colin and Dufour, 1968] provide models which may explain the gross features of the latitudinal variation of the ion composition at low and mid-latitudes, these interpretations do not apply in the trough zone and further poleward. In particular, the model developed by Mayr indicates that predicted ionospheric temperatures fall significantly below the observed temperatures above dipole latitudes of about 60°. This discrepancy has been attributed to a decrease in energy loss in the protonosphere, resulting from proton escape fluxes.

Several models have been proposed to explain the removal of high latitude ionization, including the magnetospheric convection model of Nishida [1966] and the concept of a 'polar wind,' proposed by Banks and Holzer [1968]. The Nishida model, which invokes the draining of high latitude field tubes by the combined action of magnetospheric convection and plasma escape from the tail has predicted characteristics of the plasmapause with which both these and earlier ion and vlf results appear to be consistent [Taylor et al., 1968].

The 'polar wind' concept provides an alternate mechanism for the ion depletion, although it appears that the abruptness frequently observed in the formation of the trough exceeds the latitudinal rate of change of gravitational escape proposed by Banks. Furthermore, the polar wind concept, like the earlier evaporational escape model of Dessler and Michel [1966], applies to the region of open magnetic field lines – a region which has as yet been assumed to lie poleward of the light ion trough zone. Diffusion across field lines is of course not ruled out, and thus the effect of the polar wind might be coupled to lower latitude field tubes. In general, the effect of some form of gravitational escape of the light ions is evident, and our results indicate that the depletion is effective at latitudes appreciably below the auroral zone.

The abruptness of the ion trough further suggests that under certain conditions a sharply defined upward expansion of the atmosphere may occur near the equatorward edge of the light ion trough, resulting in upward fluxes through which the light ions somehow escape. This possibility appears to be supported by the nearly simultaneous occurrence of the abrupt cutoff in vlf ground-to-satellite transmission. As suggested by Heyborne [1966] and Heyborne et al. [1969], the sudden vlf cutoff may well result from a rapid increase in rf absorption, attributed to increased ionization and collision frequency in the D and lower E regions. As indicated by Heyborne, an increase in D-region absorption of a factor of two is more than sufficient to explain the vlf transmission loss of 20 db. Significantly, recent direct measurements of the latitudinal variation in the neutral atmospheric density from Explorer 32 [Newton and Pelz, 1968] near 400 km reveal abrupt increases of as much as a factor of five in neutral density within 3° Λ, at latitudes and local times comparable to those of the trough zone. Such abrupt increases in the neutral density may reflect increased heating and an attendant expansion of the atmosphere at lower altitudes, an effect which would in turn be consistent with the increased collision frequency suggested by the vlf cutoff.

One possible implication of the foregoing discussion is that a significant energy source is abruptly manifested in the lower atmosphere at latitudes just equatorward of the auroral zone, and that this energy is somehow related to the simultaneous vlf-whistler cutoff and the light ion depletion. The fact that the simultaneous ion depletion and whistler cutoff has also been observed at high altitudes in the magnetosphere [Carpenter et al., 1969] provides evidence that the plasmapause and the light ion trough result from some mechanism which couples the magnetosphere with the ionosphere. Considering the evidence of neutral atmosphere expansion and vlf absorption, it is suggested that near dawn and dusk the L position of the plasmasphere boundary may in some way be linked with the penetration of energetic plasma, which may enter the lower ionosphere along field lines associated with the ion trough. Reviews of limited available data on the latitudinal distribution of precipitating particles by Bailey [1968] and Brice [1967] show that there is a hardening of the spectrum of precipitating electrons on the equatorward side of the auroral oval, with fluxes of electrons with $E \geq 40$ kev observed at lower latitudes, near the light ion trough region. This, coupled with earlier observations that a peak in the magnetosphere distribution of 40 kev electrons may under certain conditions occur at the L position of the plasmapause [Taylor et al., 1968], adds further interest to the possibility that particles with energy sufficient to penetrate and modify the particle concentrations in the D and lower E regions precipitate near the ion trough latitudes. Correlative data on thermal and energetic particles is relatively sparse, however, and a much more comprehensive study will be required to examine such possible relationships.

Poleward of the light ion trough, where the influx spectrum apparently softens, the effects of the lower energy particles may explain the fluctuating recoveries in the light ion distributions, as well as the structured vlf noise forms. In particular, the vlf auroral hiss region has been associated with the precipitation of kilovolt energy particles [Gurnett, 1966; Jorgenson 1968]. Recently Lund and Hunsucker [1967] have compared simultaneous topside sounder electron densities and auroral backscatter data, attributing rapid fluctuations of a factor of two to five in N_e to ionization enhancements resulting from precipitation of kilovolt (or lower) range electrons.

SUMMARY

Examination of a limited sample of ion composition and vlf data obtained between about 400 and 1500 km in a polar, dawn-dusk orbit reveals that:

(1) The high latitude ionospheric distributions of H^+ and He^+ are rapidly depleted, forming a light ion trough near 60° Λ. This trough is often quite steep, as $n(H^+)$ and $n(He^+)$ decrease by as much as an order of magnitude within 3°Λ.

(2) Coincident with the light ion trough, the rate of reception of whistlers and the ground-to-satellite propagation of vlf signals also decrease abruptly within $3°\Lambda$, the transmitted vlf signal dropping by as much as 20 db in this interval.

(3) Poleward of the light ion-vlf cutoff, patchy regions of fluctuation in $n(H^+)$ and $n(He^+)$ are observed in the auroral zone, where the ion concentrations change by factors of two to five within several degrees or less. There is limited evidence that the vlf hiss in the range 5-10 kHz, which is frequently observed in the same region, may be associated with the fluctuations in the auroral ionosphere.

Clearly, the available data are insufficiently complete to permit the determination of a conclusive model of the high latitude ionosphere and the mechanisms which may perturb it. More detail is required, not only in the form of additional interdisciplinary data correlations, but also in terms of the local time variation in the phenomena discussed. Hopefully, these preliminary studies and the tentative picture which they suggest will serve to stimulate further detailed studies of this dynamic region.

ACKNOWLEDGMENTS

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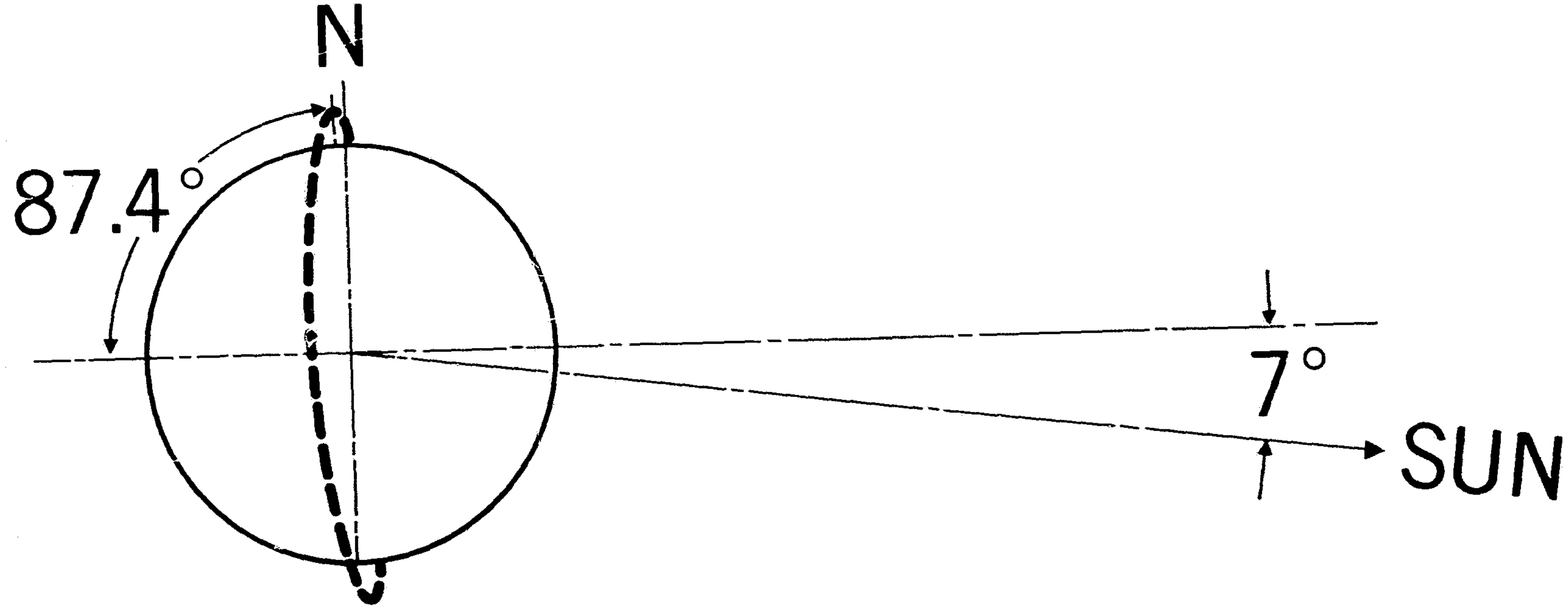
ILLUSTRATIONS

Figure 7. Broadband vlf recordings obtained on October 22, 1965 in the southern hemisphere, crossing from dawn to dusk portions of the orbit. The whistler cutoff near 1127 correlates with the light ion trough shown in Figure 6. Note vlf hiss activity, pronounced between 1135 and 1136, where fluctuations in $n(H^+)$ and $n(He^+)$ are most significant.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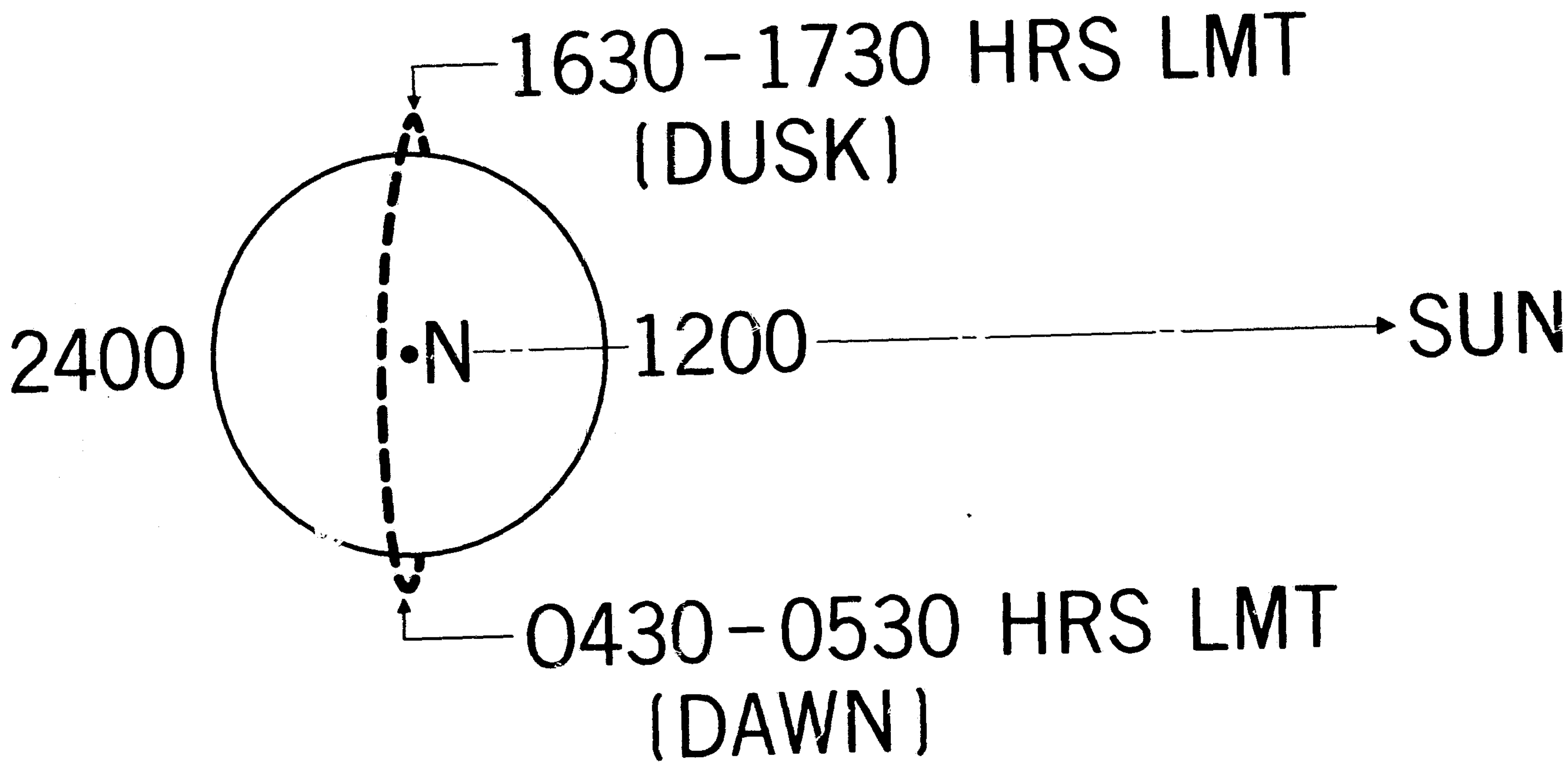
87.4°
7°
SUN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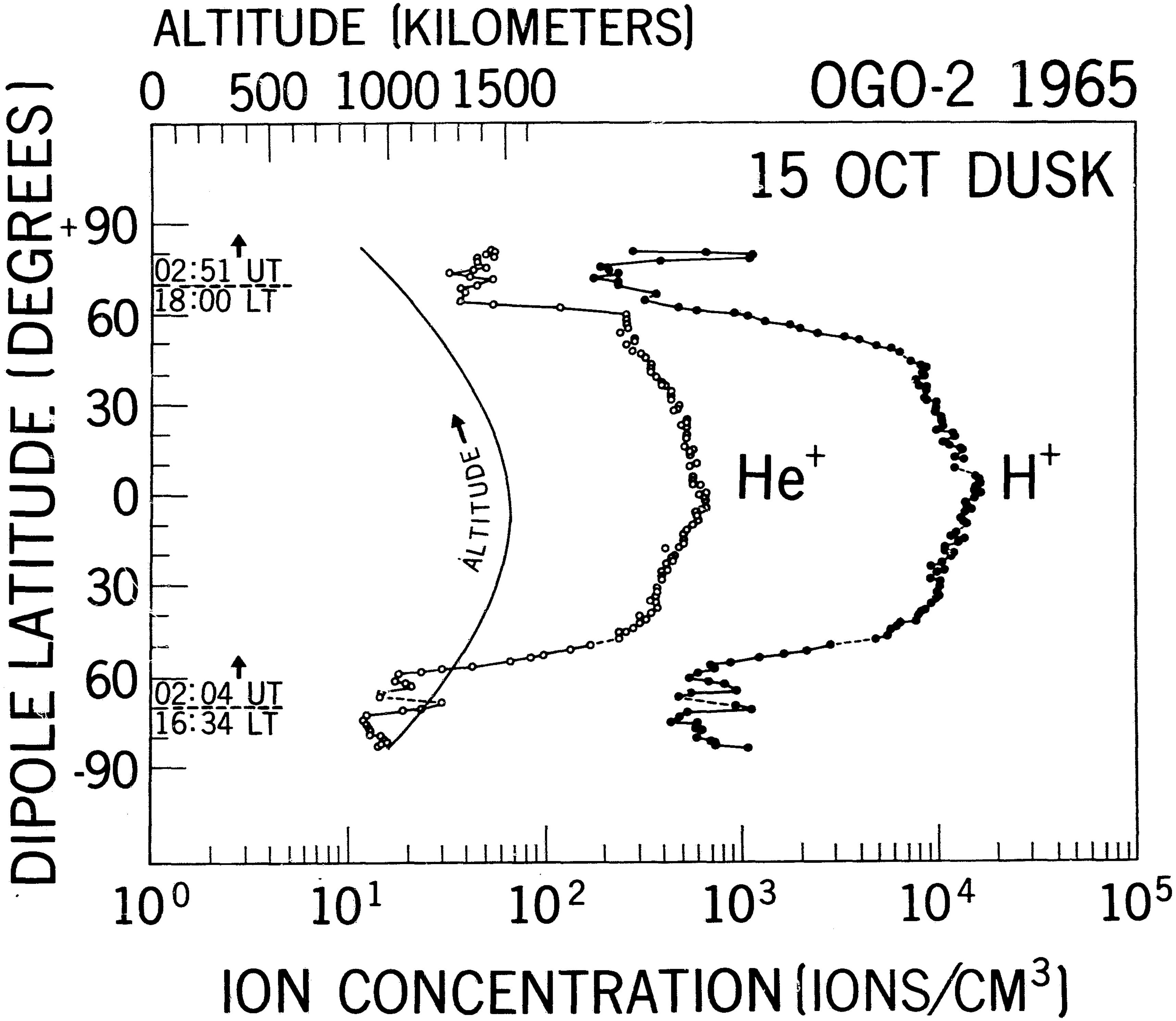
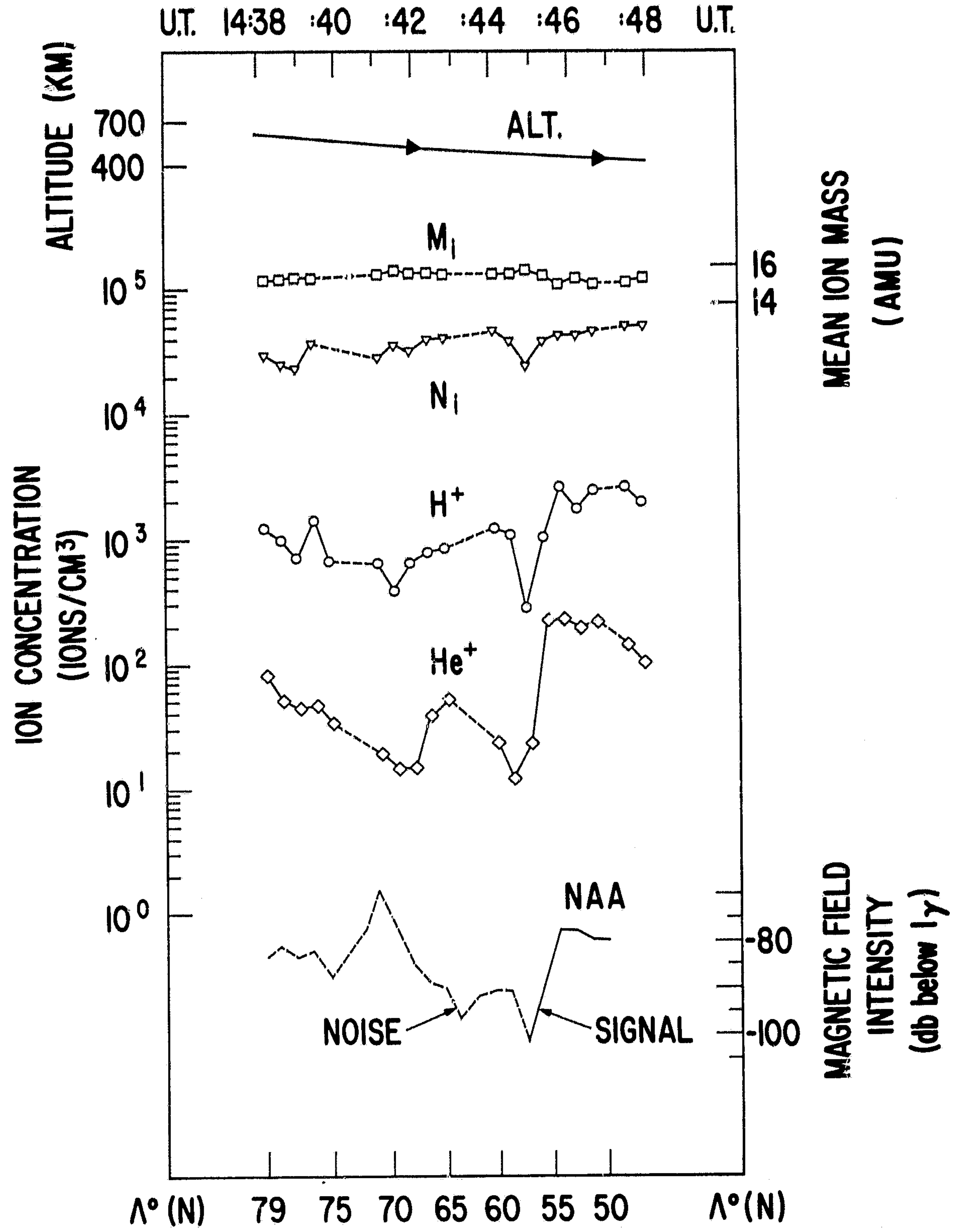
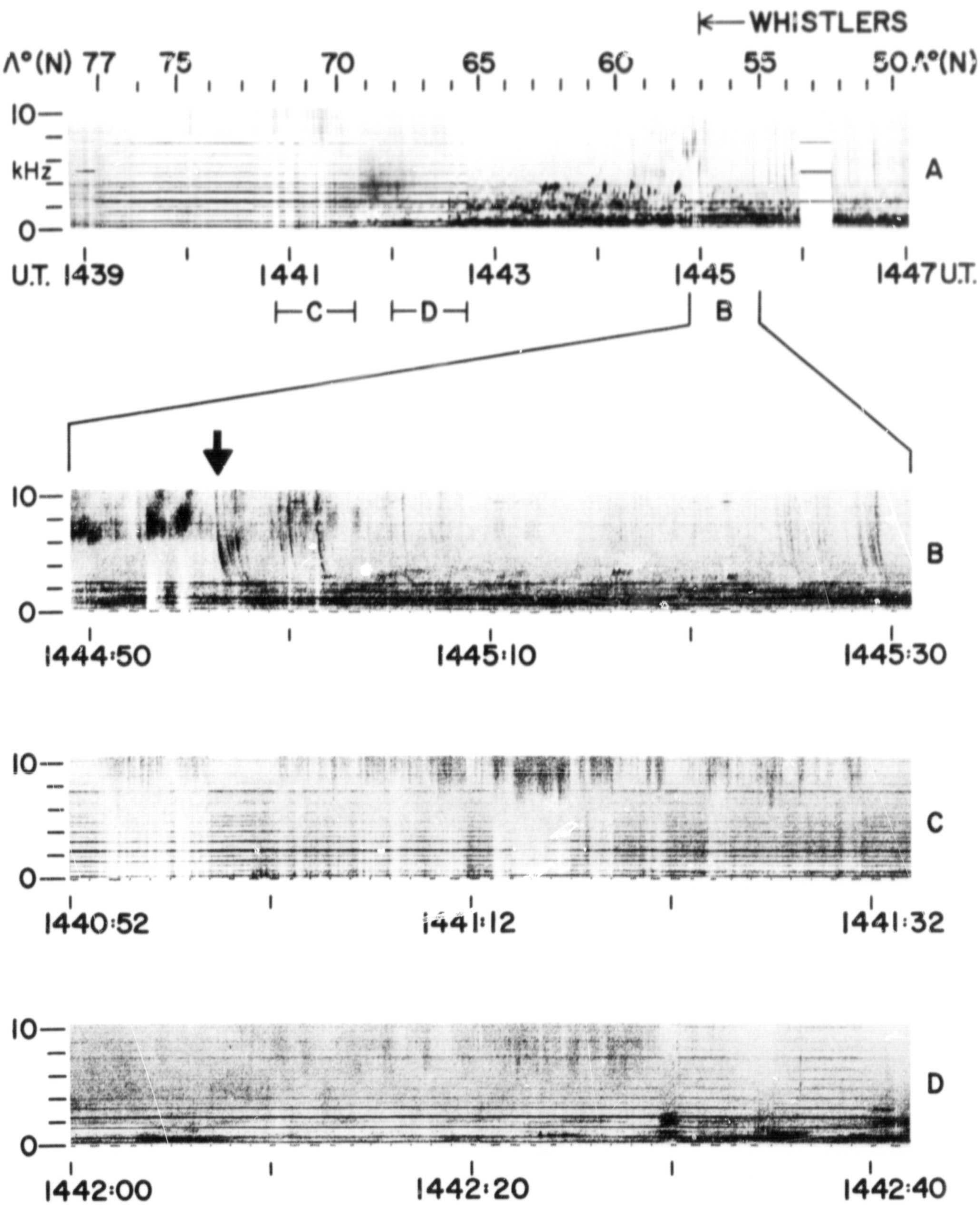
(DUSK)
2400
N
1200
SUN
0430 – 0530 HRS LMT
(DAWN)



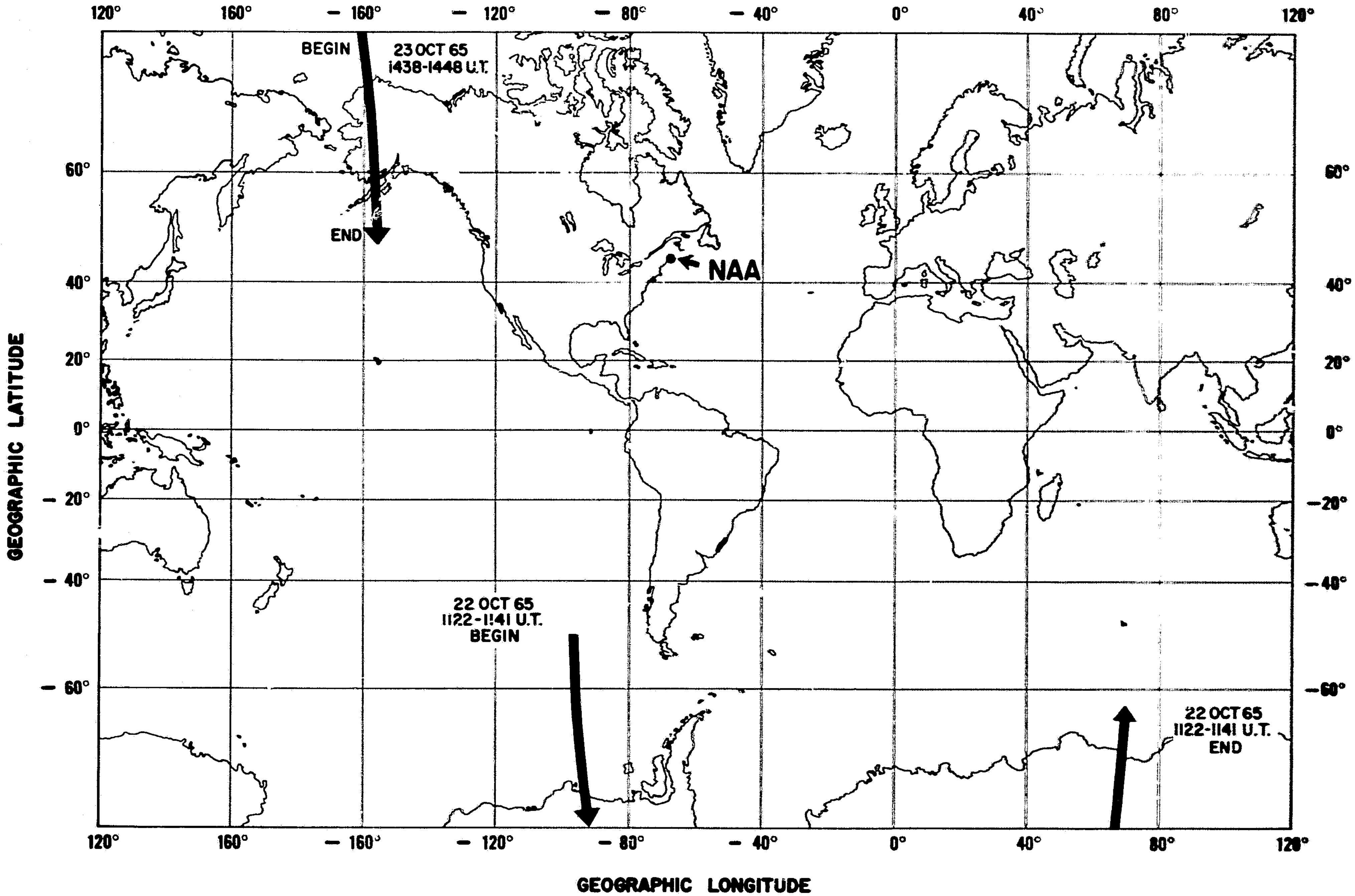
OGO-2 1965
15 OCT DUSK
ALTITUDE (KILOMETERS)
0
500
1000
1500
DIPOLE LATITUDE (DEGREES)
+90
60
30
0
30
60
-90
02:51 UT
18:00 LT
02:04 UT
16:34 LT
ALTITUDE
He+
H+
10^0
10^1
10^2
10^3
10^4
10^5
ION CONCENTRATION (IONS/CM^3)



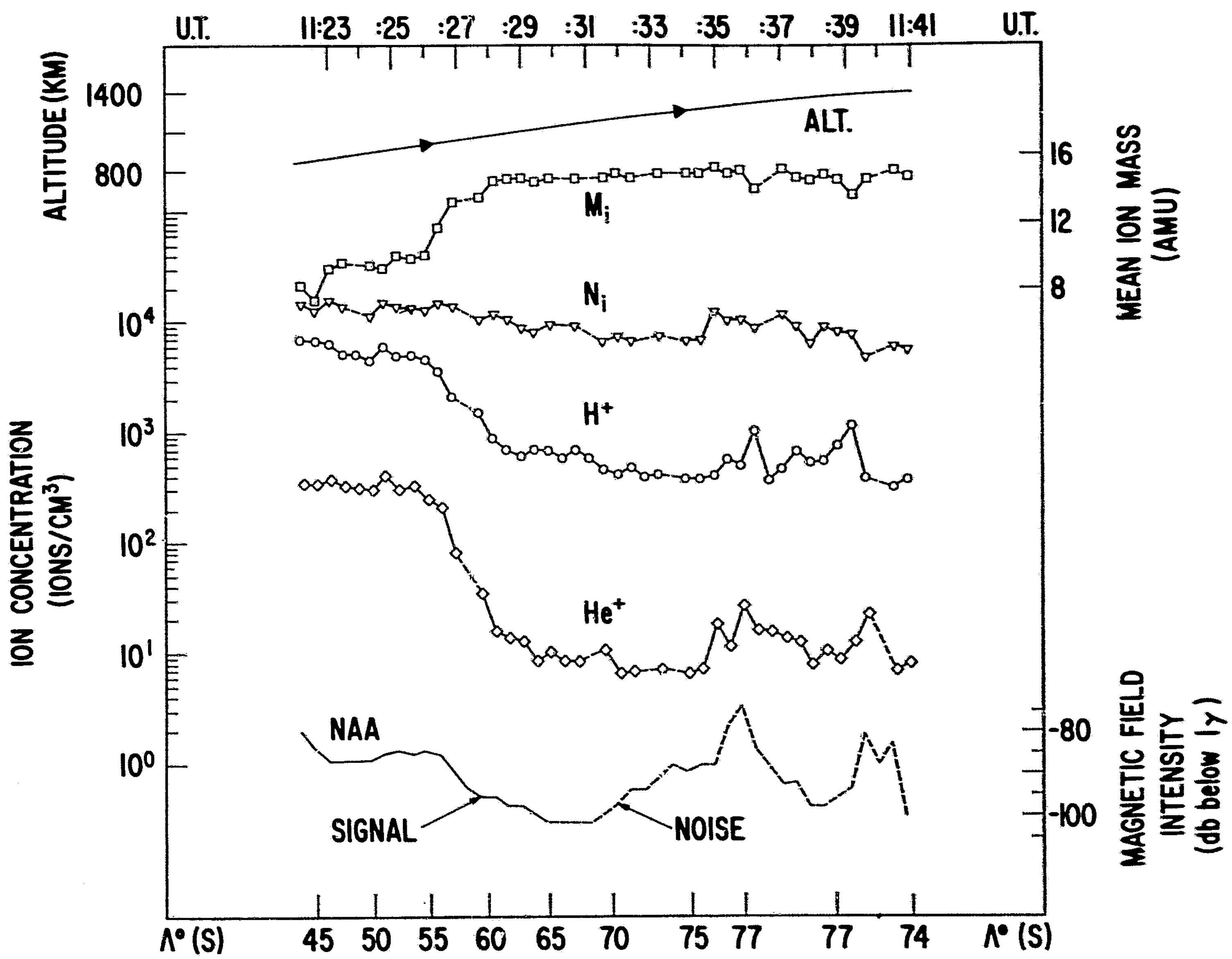
U.T. 14:38 :40 :42 :44 :46 :48 U.T.
ALTITUDE (KM)
700
400
ALT.
M
N
H+
He+
ION CONCENTRATION (IONS/CM3)
10 5
10 4
10 3
10 2
10 1
10 0
MEAN ION MASS (AMU)
16
14
NAA
NOISE
SIGNAL
-80
-100
MAGNETIC FIELD INTENSITY (db below 1γ)
Λ° (N) 79 75 70 65 60 55 50 Λ°(N)

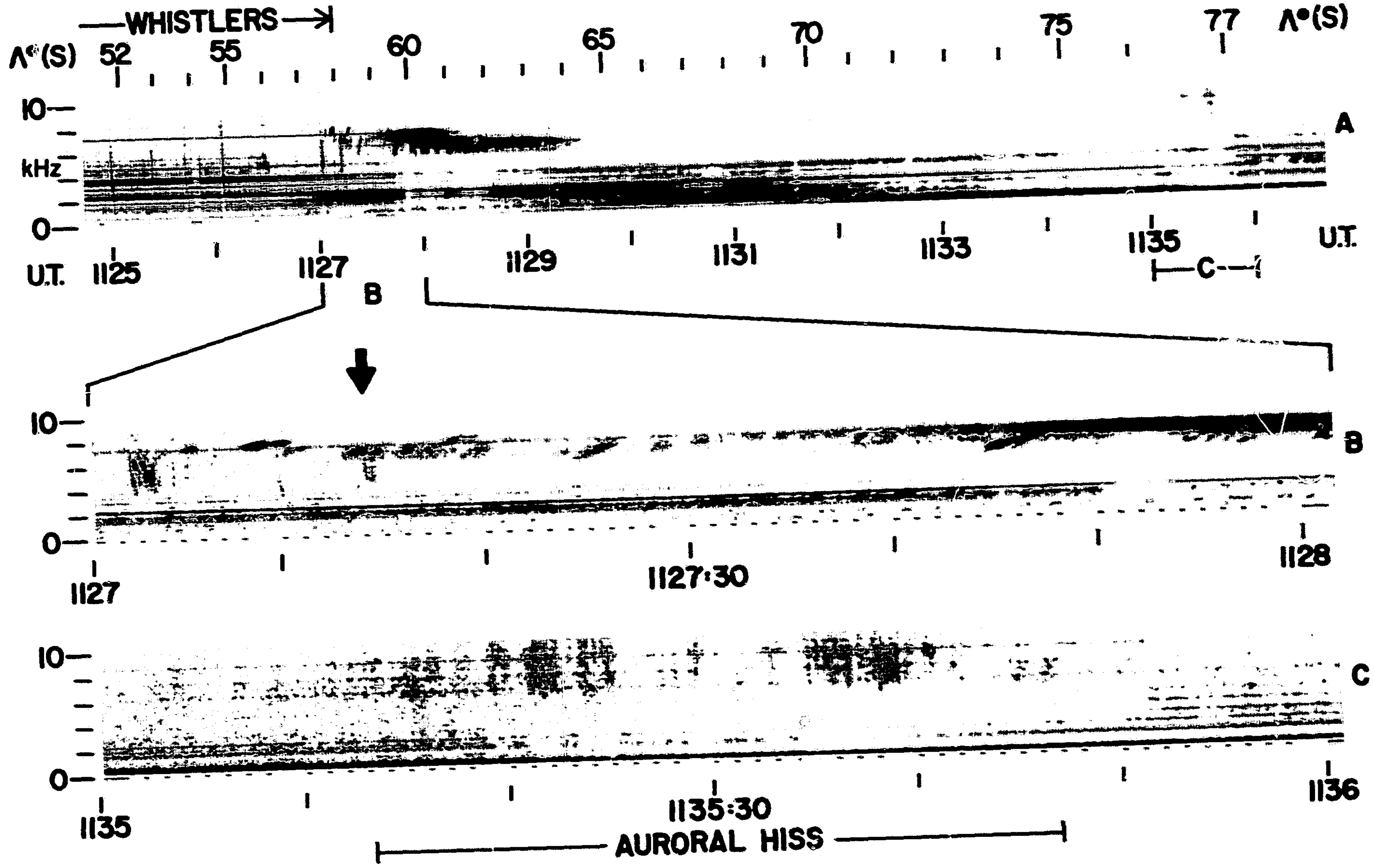


WHISTLERS
Λ°(N) 77 75 70 65 60 55 50 Λ°(N)
10
kHz
0
A
U.T. 1439 1441 1443 1445 1447 U.T.
C
D
B
10
0
B
1444:50 1445:10 1445:30
10
0
C
1440:52 1441:12 1441:32
10
0
D
1442:00 1442:20 1442:40



BEGIN
23 OCT 65
1438-1448 U.T.
END
NAA
22 OCT 65
1122-1141 U.T.
BEGIN
22 OCT 65
1122-1141 U.T.
END
GEOGRAPHIC LATITUDE
GEOGRAPHIC LONGITUDE


U.T.
11:23
:25
:27
:29
:31
:33
:35
:37
:39
11:41
U.T.
ALTITUDE (KM)
1400
800
ALT.
MEAN ION MASS (AMU)
16
12
8
M_i
N_i
H^+
He^+
ION CONCENTRATION (IONS/CM^3)
10^4
10^3
10^2
10^1
10^0
NAA
SIGNAL
NOISE
MAGNETIC FIELD INTENSITY (db below 1γ)
-80
-100
Λ° (S)
45
50
55
60
65
70
75
77
77
74
Λ° (S)



WHISTLERS
Λ°(S)
52
55
60
65
70
75
77
Λ°(S)
10
kHz
0
A
U.T.
1125
1127
1129
1131
1133
1135
U.T.
C
B
10
0
B
1127
1127:30
1128
10
0
C
1135
1135:30
1136
AURORAL HISS