A Qualitative Local Time Survey of VLF Events

by

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ABSTRACT

This is a qualitative study of wide band VLF events as a function of magnetic local time using data from the Injun 5 satellite. The data included was taken at low altitudes (1000 km to 2500 km) during magnetically "quiet" times as determined from the K_p index and at latitudes greater than 50° INV. The results are summarized in eight actual passes which are representative of the data in eight equally spaced sectors of magnetic local time. The findings agree, generally, with previous studies, showing that VLF hiss occurs mostly during early local afternoon, saucers during local evening and early morning and ELF hiss and chorus during daylight hours.

I. INTRODUCTION

Several studies of Very-Low-Frequency (VLF) events in the magnetosphere have been carried out [Gurnett, 1966; Cauffman and Gurnett, 1968; Taylor and Gurnett, 1968; and Barrington _et al._, 1971] classifying various types of events and also attempting to find spatial and temporal patterns of occurrence. This study is an attempt to qualitatively describe the variation with Magnetic Local Time (MLT) of several types of VLF events. The results are to be in the form of a display of typical mid-to-high-latitude satellite passes from various MLT sectors at low altitudes (1000 to 2500 km). The goal is to choose a satellite pass through each of eight different MLT sectors which is representative of most other passes in the respective sector. Qualitatively, the results should be similar to a statistical study, with the data in a different form. This type of study should be more sensitive to atypical data and serve as a guide to the correlation of statistical studies and actual data. Does a typical piece of data correspond well to what statistical studies predict?

II. DESCRIPTION OF THE STUDY

The data was acquired from the Injun 5 spacecraft which is in a polar orbit inclined at 80.7° with altitude ranging from 677 km to 2528 km. A magnetic loop antenna composed of 6 turns of wire on a magnesium form 55.8 cm in diameter provides the magnetic component of the signal. Two conducting spheres separated by 2.85 m are used as an electric dipole antenna. An electric and a magnetic receiver are used, each operating on two bands: 30 Hz to 650 Hz (Lo-band) and 650 Hz to 10 kHz (Hi-band). This study uses mainly Hi-band data. A more detailed description of the instrumentation may be found in Gurnett _et al._ [1969]. An important note, however, is that the receivers are automatic gain controlled (AGC) such that the gain is increased in the absence of a large signal, and vice-versa. A consequence of using an AGC receiver is that direct comparison of two events separated in time cannot yield any information on the relative intensities of the events unless calibrated digital data is referred to.

Initial data processing puts the data into the form of frequency-time spectrograms in which an event is recorded at a particular frequency and time with an intensity related to the darkness at that point; higher intensities being darker. Figure 2, which is discussed in greater detail at a later time, provides examples of these spectrograms. Note that there are two channels, one providing electric information, the other magnetic.

The criteria used to choose data are as follows:

(1.) $K_p \leq 2$ to assure "quiet" magnetic conditions,

(2.) Passes must come within 2° of the magnetic pole to assure that the auroral oval would not be crossed tangentially and that MLT would remain constant,

(3.) Passes should cover as much of the orbit from 50° INV to the pole as possible, and

(4.) Since data from each MLT sector exists for periods of time separated by months, data was surveyed from several of these periods to cancel long-time effects (on the order of months).

One consequence of the above criteria was that nearly all data was taken from the northern hemisphere due to positioning of tracking stations. Also, the criteria eliminated large amounts of data which eventually limited much statistically oriented study which might otherwise have been explored.

Three hour local time sectors (i.e., 0-3, 3-6 MLT etc.) were used to divide the data into eight segments. Data meeting the criteria listed above from one MLT sector was surveyed as a contiguous entity and patterns and characteristics were noted by the analyst. By doing only one segment at a time, it was thought that the analyst could develop a better feeling for the type of data there. After all data from a particular sector had been studied (generally on the order of 20 passes), a general trend for that sector was written down from notes and memory. Then, by going through the data once more, 5 passes were chosen as being representative and showing cohesion to the general trend.

The five representative passes from each sector were then used to arrive at general trends of occurrence in local time, and rough estimates on the intensities of events. These studies will be described in greater detail in the discussion of results.

As a final step, one pass from each local time sector was chosen from the five to represent the data from its respective sector. The trajectories of the satellite for the chosen segments of data are plotted as INV versus MLT in Figure 1. Note that the coverage is poorer at local night. This is a result of a power anomally on board the spacecraft which tended to limit data collection to periods during daylight hours when power could be supplied by the solar cells. These representative passes should be the anchor of this paper. The associated studies in intensities are meant only to aid in the selection process and aid in resolving points not clearly evident in the data.

III. DATA

The actual phenomena observed may be divided into four main classes designated as: ELF (Extremely-Low-Frequency) hiss, chorus, VLF hiss (also called impulsive or auroral hiss), and saucers. These have been described in the literature by Helliwell [1965] and Taylor and Gurnett [1968], among others. Figure 2 shows both electric (E) and magnetic (B) components of events typical of these four classes. ELF hiss is a fairly uniform band of hiss which is generally seen below 2 kHz and often exhibits a lower frequency cutoff. It is generally seen in the middle to high latitudes (50° to 70° magnetic latitude). ELF hiss is also seen at ground-based stations [Aarons _et al._, 1960]. Chorus is an occurrence of several discrete emissions which normally are of short duration, lasting only a few tenths of seconds and rising in frequency with time. This phenomenon is often seen in conjunction with ELF hiss and almost always appears in a band of nearly constant frequency between 0.5 kHz and 6.0 kHz. The width of the band is variable, but is usually about 1 kHz wide. Chorus has been found to have some dependence on magnetic activity [Allcock and Mountjoy, 1970]. VLF hiss consists of a wide band of noise ranging in frequency from about 2 kHz or higher to frequencies above the 10 kHz ceiling seen by Injun 5. It sometimes shows rapid fluctuations on a time scale of seconds or less and thus has been called impulsive hiss.

It also seems to be associated with the auroral zone, being found between 60° and 80° INV and has, therefore, also been called auroral hiss. Jørgensen [1966] and Gurnett [1966] have both done informative studies on this phenomenon. The fourth species of the phenomena has been given the term saucer. This is very descriptive since they appear on the spectrograms as symmetrical, V-shaped forms opening toward higher frequencies. It is thought that these are streams of up-going electrons within the trapping boundary near a stream of down-going electrons outside the boundary associated with VLF hiss.

IV. RESULTS

The results of this study must be summed up by the use of the frequency-time spectrograms for each of the local time sectors (Figures 3 through 18). Unfortunately, due to the length of some of the passes, the magnetic channel could not be displayed on the same page as the electric, but it is still possible to compare the two channels. The first general result to be derived is that virtually any of the four classes of phenomena may be found at any local time. There are some differences, for example VLF hiss seems to occur most often near 15 hours MLT and saucers show a trend of occurring mostly during evening and early morning.

The following will be a brief description of each representative pass in order to point out the various considerations involved in its selection and the general trend for its respective local time sector. Figures 3 and 4 are the electric and magnetic spectrograms for orbit 7453 from the 0 to 3 hours MLT sector. The actual MLT is listed on each of the spectrograms and is the average MLT for that pass. Because of the criterion for over-the-pole passes, all of these segments remain at virtually constant local times until the highest latitudes are reached. Figure 1 verifies this. In this part of orbit 7453, the satellite is about 950 km above the earth. The most dominant feature of this pass is its wide-band hiss between 10:16

and 10:19 UT. There is a possibility that this is VLF hiss, but there is much evidence against that idea. The latitude is generally too low for VLF hiss and the character is too homogeneous and also quite strong, magnetically, to be called VLF hiss. It is very rare in the data surveyed, but was seen in another pass in early morning MLT where there was a separate case of VLF hiss at higher latitudes. The author has labeled it temporarily as a new phenomenon, but due to the lack of enough data, has not explored it further. Other phenomena to be noticed include a band of ELF hiss in the magnetic channel before 10:19 UT. VLF hiss is nearly non-existent, but there appears to be a very faint band between 10:21 and 10:23 UT in the electric channel. The eight second breaks in the electric data here and elsewhere in the data are impedance measurements utilizing the dipole antenna and are not to be confused with naturally occurring wide-band events.

Figures 5 and 6 represent the data from 3 to 6 hours MLT. This pass was at an average altitude of about 1350 km. In the electric channel beginning with 17:56 UT and ending near 18:00 UT is a falling band of enhanced whistler-mode propagation. The lower cutoff of this band is known as the lower hybrid resonance (LHR) frequency. Brice and Smith [1965] say the LHR frequency "defines the cutoff frequency for propagation transverse to the earth's magnetic field". This band is displayed more prominently in other passes. There is ELF hiss in this pass before 18:04 UT in both channels, occurring in two bands less than 1 kHz in width below 2 kHz. The spikes near 18:02 UT especially in the magnetic channel appear to be chorus. Finally, notice the VLF hiss in the electric channel between 18:04 and 18:06 UT. The invariant latitude covered by the hiss is that of the auroral zone. In this, as in most cases, there is very little activity poleward of the VLF hiss.

Figures 7 and 8 represent 6 to 9 hours MLT. Here the electrostatic LHR band is very prominent at low latitudes. The fairly wide band of hiss below 3 kHz is ELF hiss. There are also some discrete emissions near 17:36 UT which appear to be quite interesting in character. VLF hiss becomes more prominent in this pass, commencing at 17:41 UT in the electric channel, and even showing up in the magnetic channel at 17:44 UT. The altitude of this pass is about 2200 km.

Orbit 3966 (Figures 9 and 10) represents the data from 9 hours to noon MLT. The altitude for this pass is about 2500 km. This pass is almost identical in character to orbit 4196. The double band of ELF hiss is similar, and there is chorus, especially near 19:54 UT. Again, VLF hiss is prominent with the magnetic component becoming visible at 20:00 UT. It is interesting to note that the latitude at this point is about 85° INV. This is nearly 10° higher than the center point of the VLF hiss for the 3 to 6 hour MLT pass. The auroral oval, similarly, lies at a higher latitude near local noon than it does at local midnight.

Figures 11 and 12 (12 to 15 hours MLT) are of orbit 3820 which is at altitudes near 2450 km. The LHR band is of slightly different character, being more of a solid band, falling with increasing latitude. At 19:43 UT there is a band of chorus between 5 and 6 kHz in the electric channel. Ungstrup and Jackerott [1963] distinguish between this chorus (normal) above 2 kHz and at middle latitudes and the chorus seen previously in the morning passes called polar chorus. Polar chorus occurs at higher latitudes and below 2 kHz. Polar chorus is also seen in this pass, mostly evident in the magnetic channel. A massive display of VLF hiss begins at 75° INV and extends for nearly 15°. The magnetic component is quite strong at times and seems to have a more unified structure than any of the previously discussed magnetic VLF hiss events. ELF hiss seems to occur in this pass at the lower latitudes, but is not well defined.

Figures 13 and 14 represent the data from 15 to 18 hours MLT. The altitude of this pass is around 2500 km. ELF hiss occurs before 04:35 UT, and a very good example of polar chorus is found near 04:30 UT. The saucer at 04:35 is quite spectacular and seems to be more complex in structure than the classical saucer, as seen in Figure 2. Poleward from that is VLF hiss, relatively limited in latitude, but also somewhat intense magnetically since it was detected quite clearly by the magnetic receiver. The relation of the saucer and VLF hiss to up-going streams of trapped electrons and down-going untrapped electrons respectively, would seem to be strengthened by this case, noting the close proximity of the two near the probable trapping boundary with the saucer closer to the trapping region.

The data from 18 to 21 hours MLT is represented in Figures 15 and 16. This segment of orbit 5627 is about 2000 km high. The LHR band is somewhat different in that between 08:23 and 08:24 UT there is a definite magnetic component. This may be evidence of a new type of phenomena, although it appears in most other respects to be associated with the LHR. Both ELF hiss and chorus exist in the lower latitudes here. A saucer appears at 0826:30 UT which is followed by VLF hiss both in the electric and magnetic channels. Scattered throughout the upper latitudes are some discrete emissions which may be some type of interference. A strange occurrence is the saucer centered at 08:34 UT nearly directly over the pole. Only half of it is visible in the figures, but it extends for a total length in time of nearly 2 minutes. This is an exception to the usually quiet pole.

Finally, Figures 17 and 18 represent the data from 21 to 24 hours local time. The altitude for this pass averages 2475 km. This pass is peculiar in many ways since the effects of limited coverage are felt most here. There were few passes from which to draw a trend and from which to choose a representative pass. Most existing passes are short like this one and, therefore, the lower latitudes are not seen at all. (Notice that this is a southbound pass.) The two saucers in the electric channel are the most prominent events, although there appears to be VLF hiss between the two events. The phenomenon near 00:40 UT appears to be static interference of unknown origin.

These passes, with the possible exception of orbit 1377 just mentioned, represent fairly accurately the data found in their respective local time sectors. As with any real data, there are always atypical events. An example would be the pole-centered saucer in orbit 5627. The study was designed to be qualitative in nature, partially to allow such anomalies to show up. The fact that they occur should occasionally be pointed out, and a study of this type is sensitive enough to do this.

Left as they are, the actual local time dependencies of some of these events are doubtful. The only obvious fact is that virtually any of the events may be found at any local time. A frequency of occurrence study was not carried out on the data chosen for this paper because there was not enough to give statistically significant results. In order to do this the criteria would have to be changed to allow orbits not directed over the pole, etc., to increase the volume of data. In a qualitative way, however, the process of choosing a representative orbit is a non-statistical frequency of occurrence study. The results of this give maximum occurrence of VLF hiss near 15 hours MLT and both ELF hiss and chorus during daylight hours. The latter two are said with reservation, however, since they both occur at most times frequently.

To obtain some typical values for the intensities of some of these events, spectral densities were computed from calibrated field strength data and bandwidths of the events (Figures 19 and 20). This could only be done where only one event was present at a particular time, since the field strength data was for the full bandwidth of the receiver. Since ELF hiss and chorus (and even the LHR band) frequently occur together, this limited the number of points computed. The electric and magnetic spectral densities are in the units volts^2 m^{-2} Hz^{-1} and the magnetic units are gamma^2 Hz^{-1}.

VLF hiss reaches higher intensities in the electric channel than the other two phenomena. On the other hand, the magnetic component of VLF hiss is generally lower than that for ELF hiss and chorus. It is not possible to obtain a good relation to local time for these points since no attempt was made to measure the peak values of an event and the dynamic range for any particular event, especially VLF hiss, is large. Also, too few points are available to compute averages with any statistical significance. In the magnetic plot, however, the VLF hiss is not much greater than the sensitivity threshold for the receiver and the events are quite limited in time span. This means most of the points are near the peaks of the events and there does seem to be a definite trend with local time. The peak occurs near local noon. While the intensity peak does not necessarily have to correspond to the frequency of occurrence, they fall within about 3 hours of each other, the resolution of the study. Also, since the electric-to-magnetic field strength ratio does not remain constant in a plasma, the electric component's peak may not coincide with the magnetic peak.

Gurnett [1966] has done a frequency of occurrence study of VLF hiss using a magnetic loop antenna on Injun 3 and finds VLF hiss mainly in the period from noon to midnight with peaks near 17 hours and 22 hours local time. Here, the magnetic frequency of occurrence peak does not compare with the magnetic intensity peak of VLF hiss found in the present study, although this paper's frequency of occurrence result is closer to that of Gurnett's. Barrington et al. [1971], using a dipole antenna on the Alouette 2 satellite, finds maximum intensities of VLF hiss near local noon, tending to agree with the magnetic findings of this study. The same survey includes a frequency of occurrence study of ELF hiss showing a daylight dependency. Taylor and Gurnett [1968] seem to agree with this result. Thus, there seems to be general, though not complete, agreement between the literature and this paper on the approximate local time dependence of these phenomena.

The dependence of the occurrence of saucers on magnetic local time has not been discussed yet. In this survey, few saucers were seen, but they all occurred between 15 and 6 hours MLT. Taylor [1973] has collected data on large numbers of saucers seen by Injun 5. No attempt to normalize the data was made, but if there is any inhomogeniety in total number of passes per local time sector, there would be more in local day due to the power problem in darkness. Even so, on the order of 90% of the saucers found, lie between 15 and 6 hours MLT. The normalization process would tend to substantiate this figure.

V. DISCUSSION

This study can only agree with previous work in a qualitative way. No real attempt has been made to do a statistical survey of VLF events. Any work in that direction has been done only to support the choices made for typical data for each sector. Qualitatively, then, one can conclude that VLF hiss occurs most often and most intensely during the period from local noon to early afternoon. Saucers show a definite trend, occurring between dusk and early morning. ELF hiss and chorus seem to be less clearly defined, being found at all local times regularly, but with a slight preference during the daylight hours. These results are easily compatible with the general trends formulated during the selection process and agree reasonably well with the literature. Since the selected passes were chosen on the basis of the general trends formulated for each sector, one can conclude that the eight representative passes are indeed reasonable models for their respective local time zones.

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FIGURE CAPTIONS

Figure 1	The trajectories of the eight representative passes showing their positions in MLT and INV as a function of time.
Figure 2	Typical examples of the four classes of VLF events studied. Top to bottom: ELF hiss, chorus, saucers, and VLF hiss. The electric components are labeled 'E' and the magnetic components 'B'.
Figure 3	Representative pass 0-3 MLT Electric.
Figure 4	Representative pass 0-3 MLT Magnetic.
Figure 5	Representative pass 3-6 MLT Electric.
Figure 6	Representative pass 3-6 MLT Magnetic.
Figure 7	Representative pass 6-9 MLT Electric.
Figure 8	Representative pass 6-9 MLT Magnetic.
Figure 9	Representative pass 9-12 MLT Electric.

Figure 10	Representative pass 9-12 MLT Magnetic.
Figure 11	Representative pass 12-15 MLT Electric.
Figure 12	Representative pass 12-15 MLT Magnetic.
Figure 13	Representative pass 15-18 MLT Electric.
Figure 14	Representative pass 15-18 MLT Magnetic.
Figure 15	Representative pass 18-21 MLT Electric.
Figure 16	Representative pass 18-21 MLT Magnetic.
Figure 17	Representative pass 21-24 MLT Electric.
Figure 18	Representative pass 21-24 MLT Magnetic.
Figure 19	Electric spectral densities of typical VLF hiss, ELF hiss, and chorus events as a function of magnetic local time.
Figure 20	Magnetic spectral densities of typical VLF hiss, ELF hiss, and chorus events as a function of magnetic local time.

A-G73-321

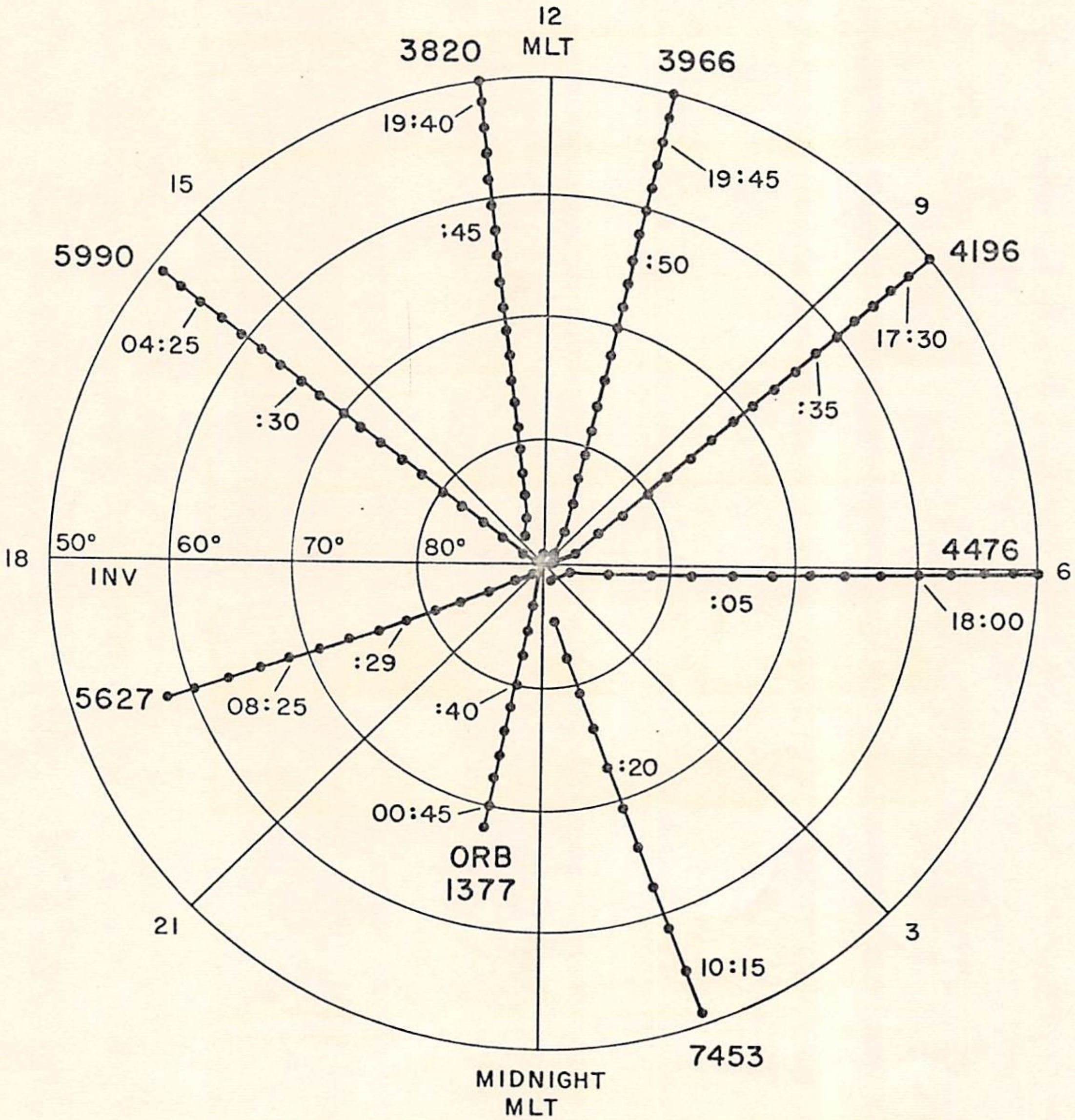
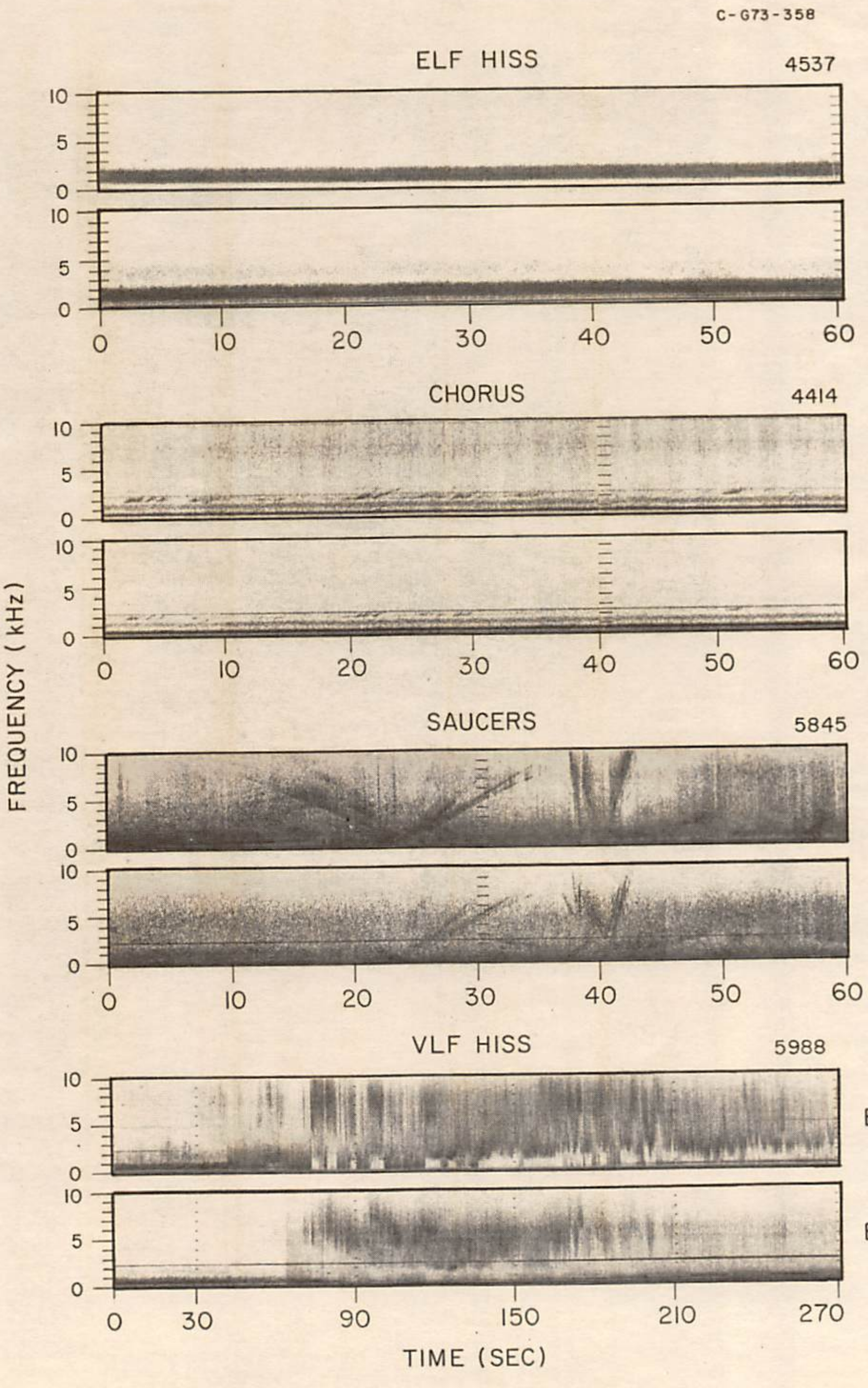


Figure 1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CHORUS
4414
SAUCERS
5845
VLF HISS
5988
E
B
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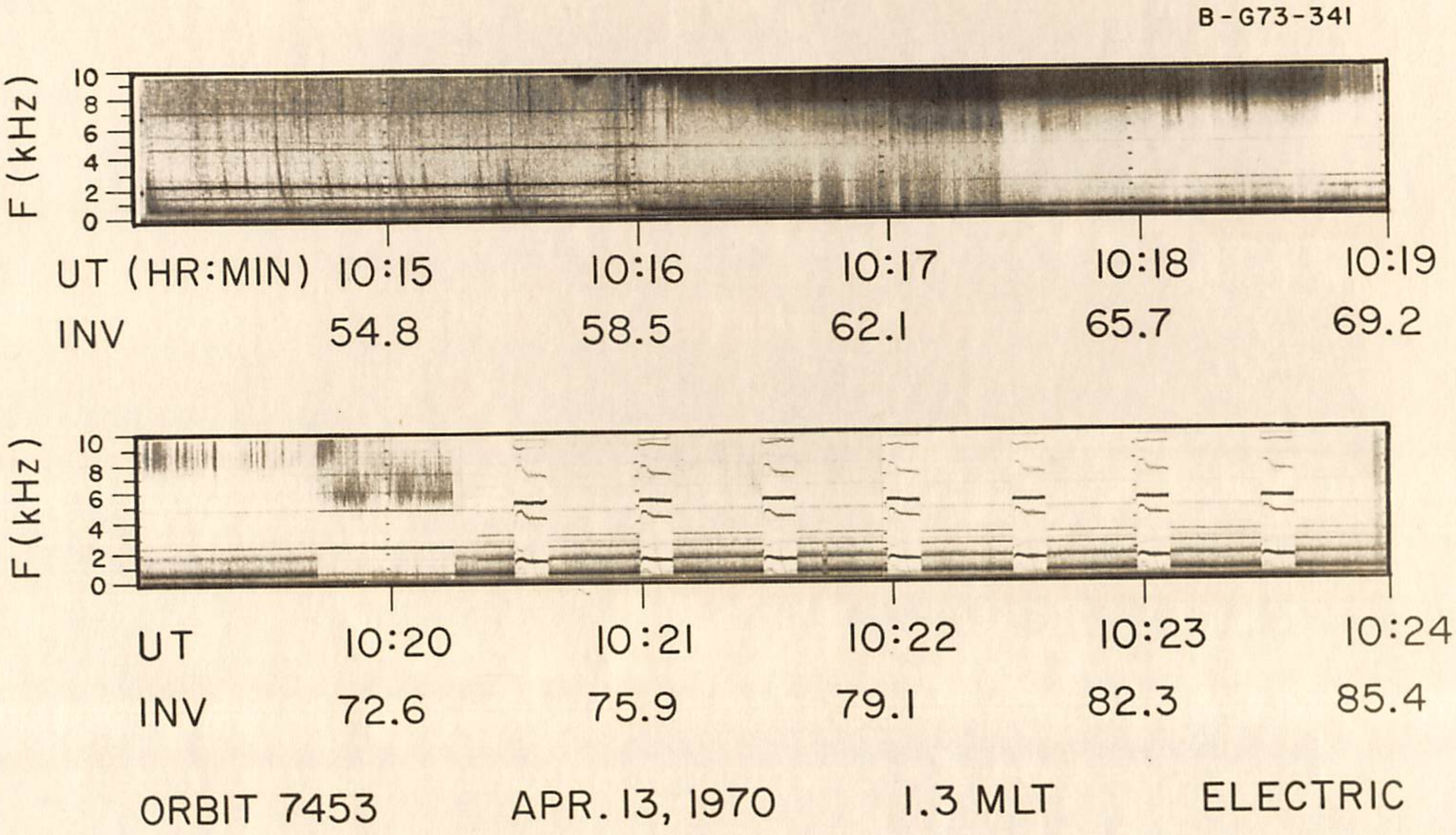
5
10
0
10
20
30
40
50
60
0
30
90
150
210
270
TIME (SEC)

Figure 2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F (kHz)
10
8
6
4
2
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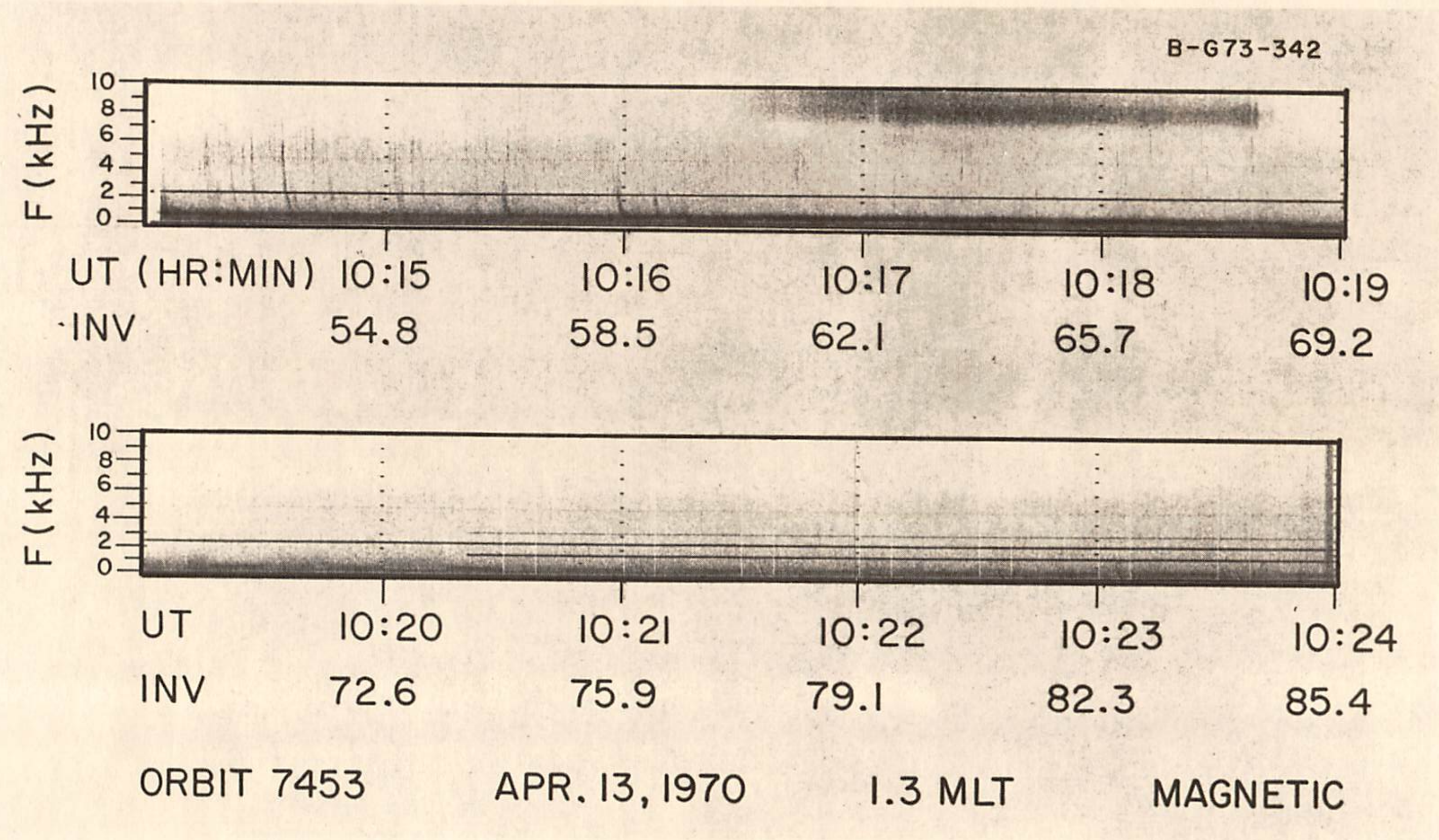
10:15
10:16
10:17
10:18
10:19
INV
54.8
58.5
62.1
65.7
69.2
F (kHz)
10
8
6
4
2
0
UT
10:20
10:21
10:22
10:23
10:24
INV
72.6
75.9
79.1
82.3
85.4
ORBIT 7453
APR. 13, 1970
1.3 MLT
ELECTRIC

Figure 3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6
4
2
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F (kHz)
10
8
6
4
2
0
UT 10:20 10:21 10:22 10:23 10:24
INV 72.6 75.9 79.1 82.3 85.4
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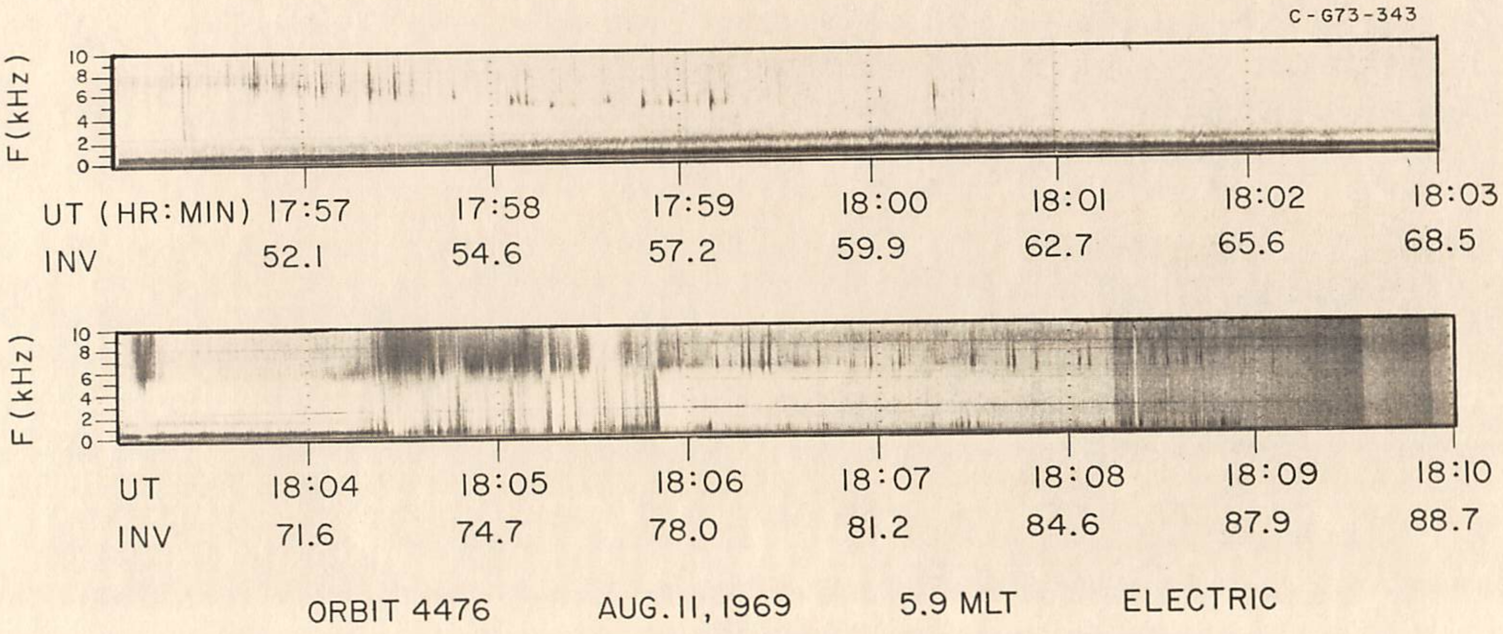
APR. 13, 1970
1.3 MLT
MAGNETIC

Figure 4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2
4
6
8
10
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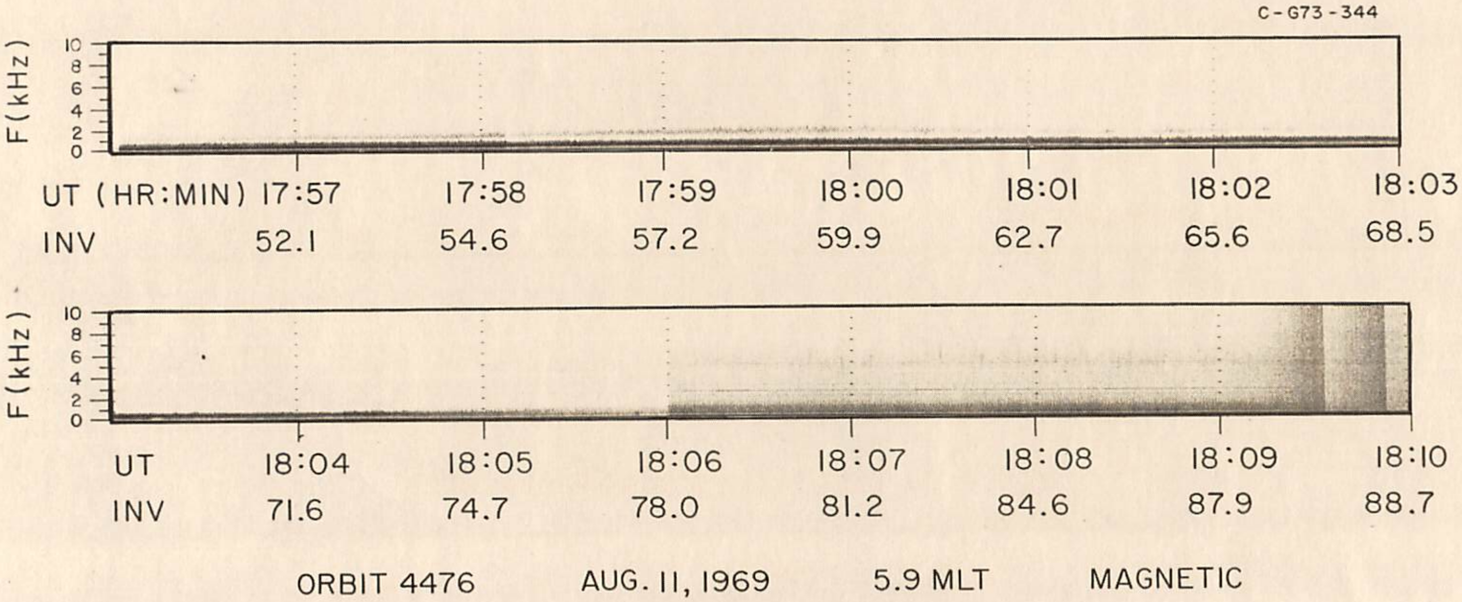
INV 52.1 54.6 57.2 59.9 62.7 65.6 68.5
F (kHz)
0
2
4
6
8
10
UT 18:04 18:05 18:06 18:07 18:08 18:09 18:10
INV 71.6 74.7 78.0 81.2 84.6 87.9 88.7
ORBIT 4476
AUG. 11, 1969
5.9 MLT
ELECTRIC

Figure 5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F (kHz)
10
8
6
4
2
0
UT 18:04 18:05 18:06 18:07 18:08 18:09 18:10
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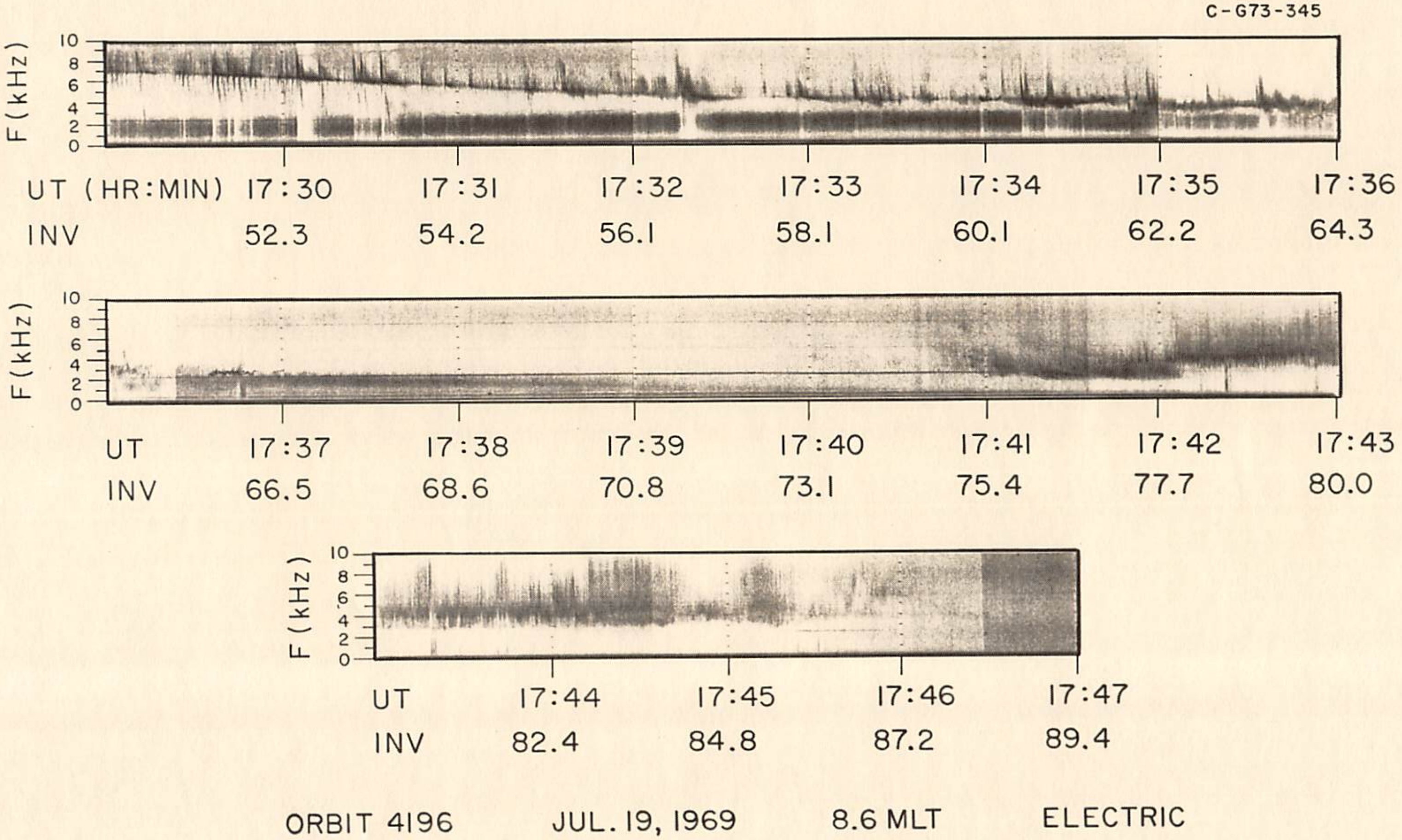
AUG. 11, 1969
5.9 MLT
MAGNETIC

Figure 6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6
8
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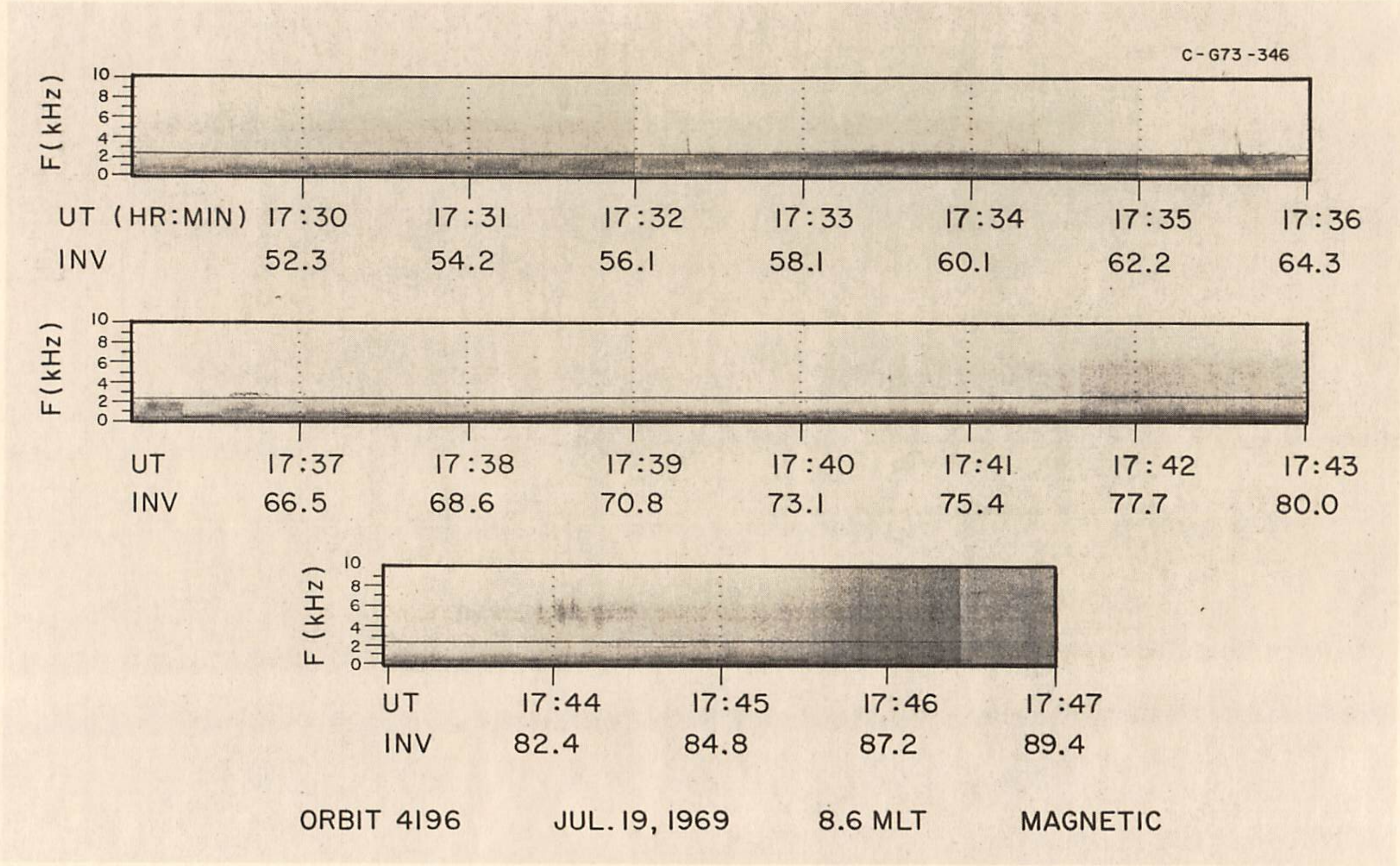
56.1
58.1
60.1
62.2
64.3
F (kHz)
0
2
4
6
8
10
UT
17:37
17:38
17:39
17:40
17:41
17:42
17:43
INV
66.5
68.6
70.8
73.1
75.4
77.7
80.0
F (kHz)
0
2
4
6
8
10
UT
17:44
17:45
17:46
17:47
INV
82.4
84.8
87.2
89.4
ORBIT 4196
JUL. 19, 1969
8.6 MLT
ELECTRIC

Figure 7


C-G73-346
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8
6
4
2
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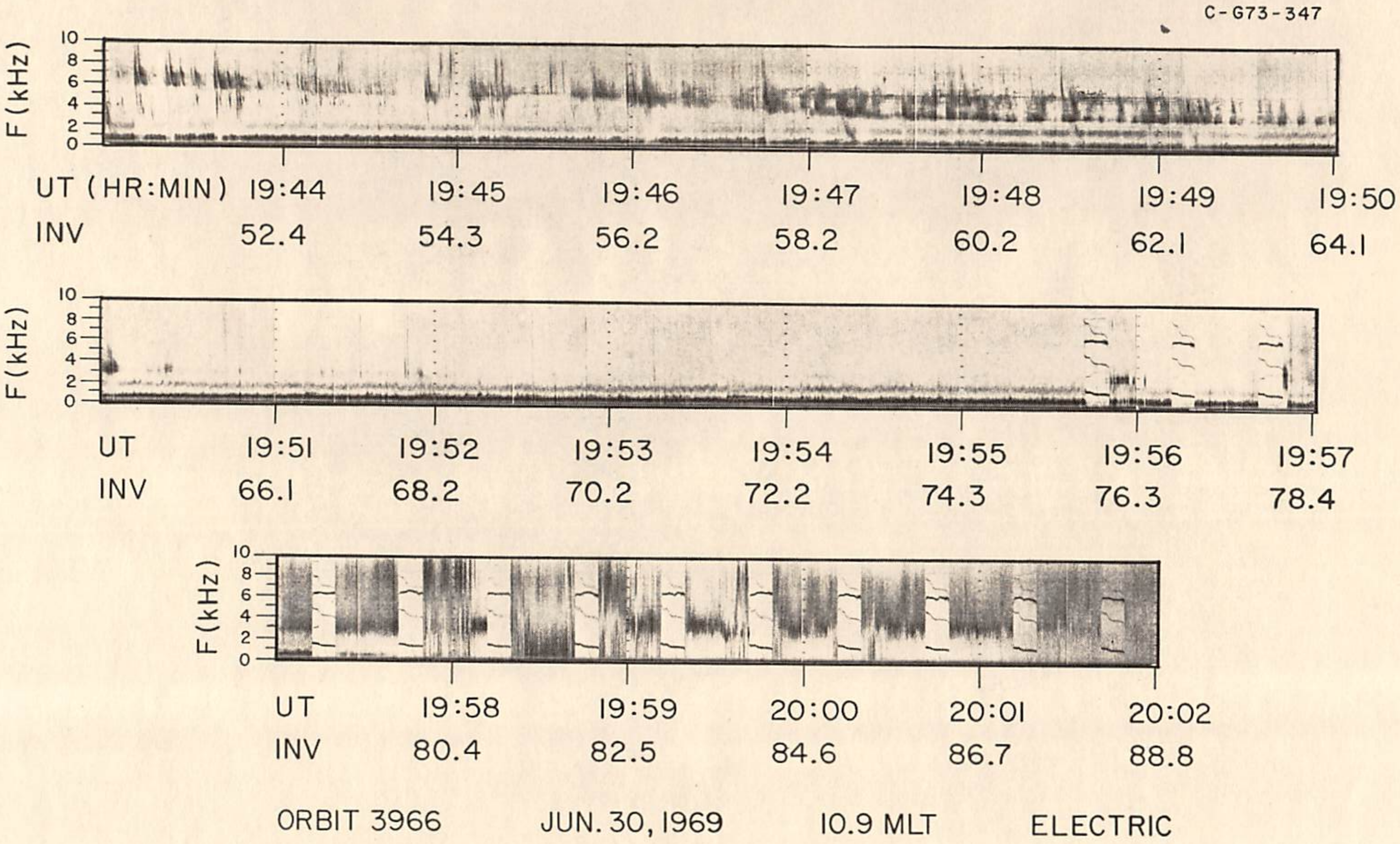
UT 17:37 17:38 17:39 17:40 17:41 17:42 17:43
INV 66.5 68.6 70.8 73.1 75.4 77.7 80.0
UT 17:44 17:45 17:46 17:47
INV 82.4 84.8 87.2 89.4
ORBIT 4196
JUL. 19, 1969
8.6 MLT
MAGNETIC

Figure 8


C-G73-347
F (kHz)
10
8
6
4
2
0
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INV 80.4 82.5 84.6 86.7 88.8
ORBIT 3966
JUN. 30, 1969
10.9 MLT
ELECTRIC

Figure 9

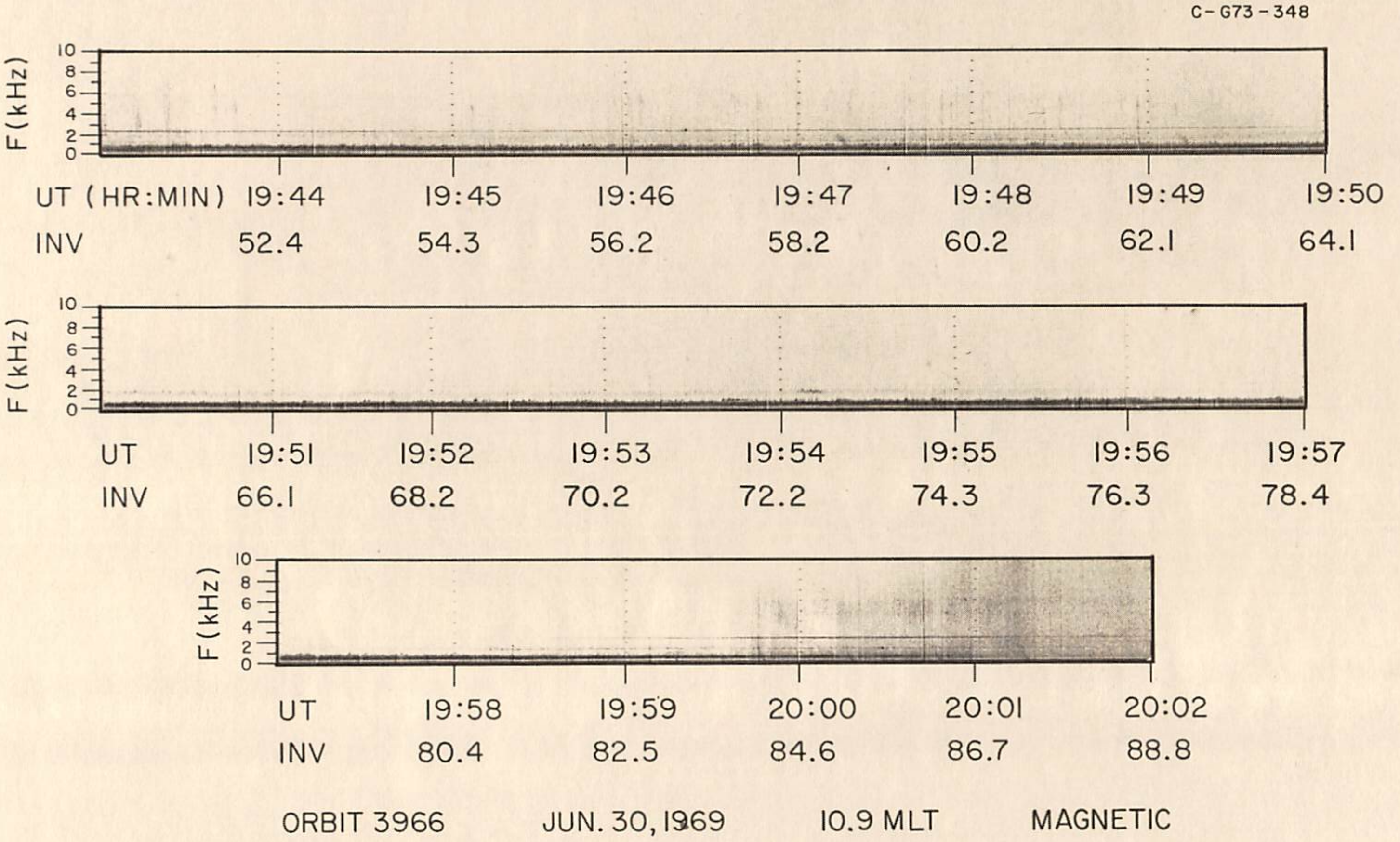
C-G73-348
F (kHz)
10
8
6
4
2
0
UT (HR:MIN) 19:44 19:45 19:46 19:47 19:48 19:49 19:50
INV 52.4 54.3 56.2 58.2 60.2 62.1 64.1
F (kHz)
UT 19:51 19:52 19:53 19:54 19:55 19:56 19:57
INV 66.1 68.2 70.2 72.2 74.3 76.3 78.4
F (kHz)
UT 19:58 19:59 20:00 20:01 20:02
INV 80.4 82.5 84.6 86.7 88.8
ORBIT 3966
JUN. 30, 1969
10.9 MLT
MAGNETIC

Figure 10

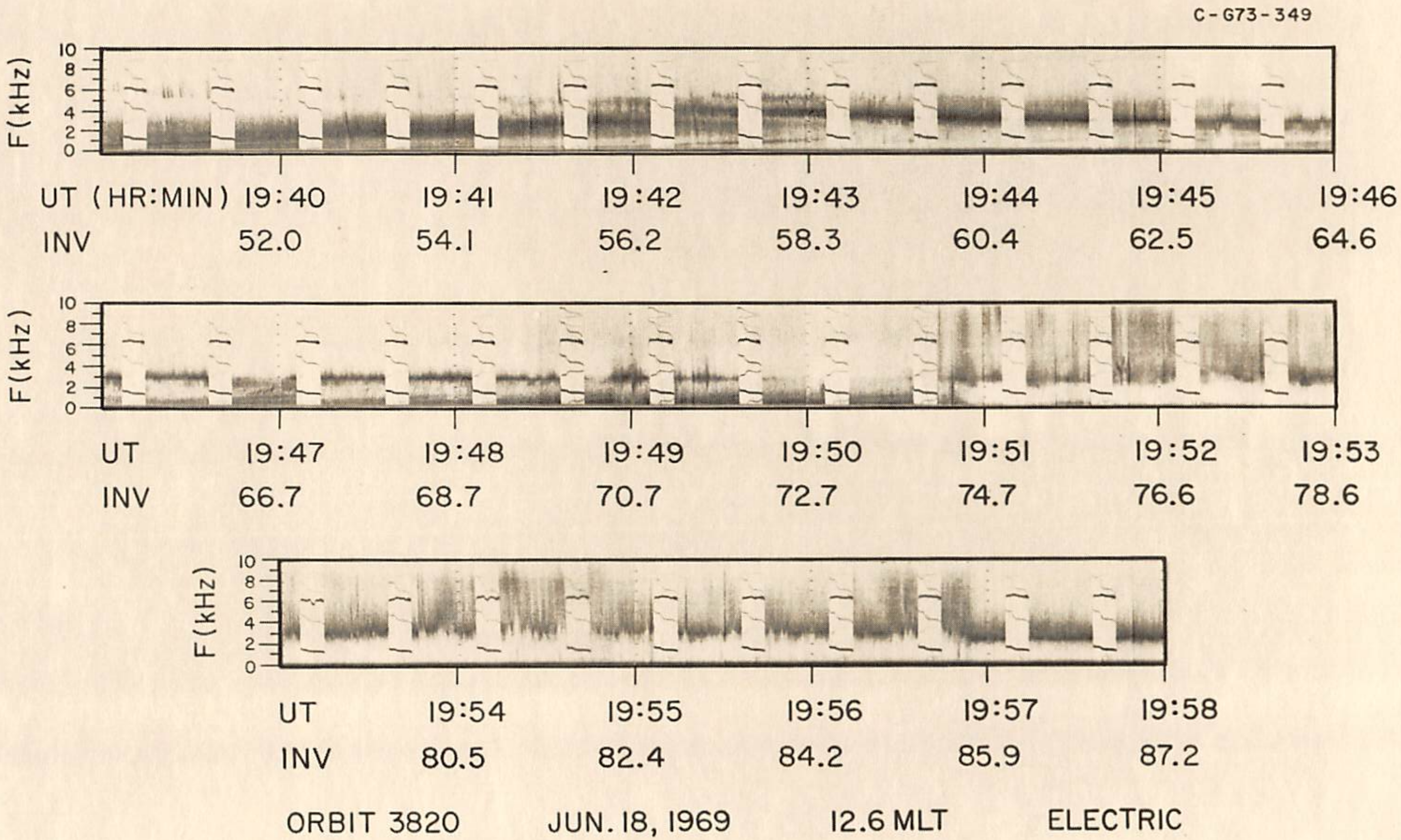
C-G73-349
F(kHz)
10
8
6
4
2
0
UT (HR:MIN) 19:40 19:41 19:42 19:43 19:44 19:45 19:46
INV 52.0 54.1 56.2 58.3 60.4 62.5 64.6
UT 19:47 19:48 19:49 19:50 19:51 19:52 19:53
INV 66.7 68.7 70.7 72.7 74.7 76.6 78.6
UT 19:54 19:55 19:56 19:57 19:58
INV 80.5 82.4 84.2 85.9 87.2
ORBIT 3820
JUN. 18, 1969
12.6 MLT
ELECTRIC

Figure 11

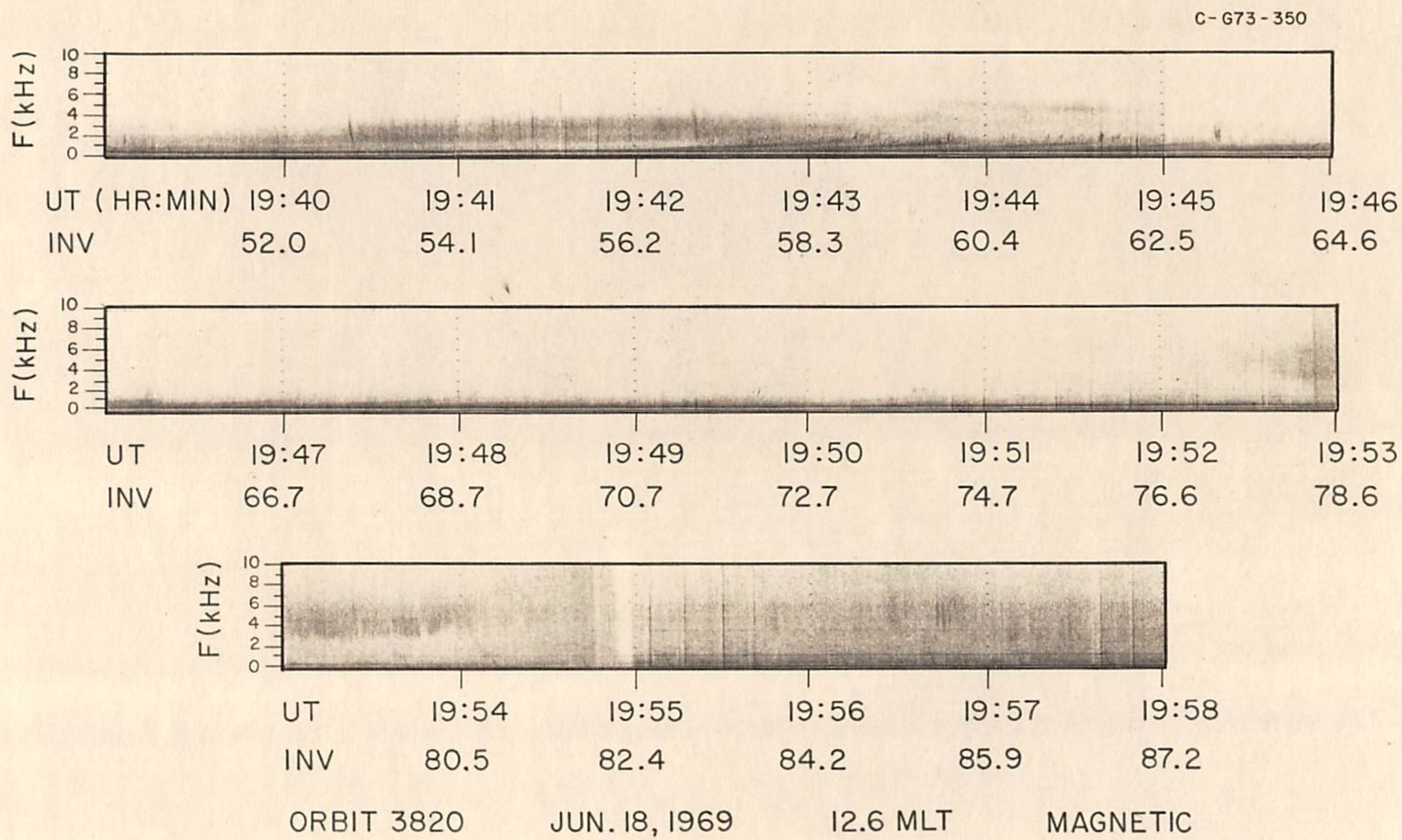
C-G73-350
F(kHz)
10
8
6
4
2
0
UT (HR:MIN) 19:40 19:41 19:42 19:43 19:44 19:45 19:46
INV 52.0 54.1 56.2 58.3 60.4 62.5 64.6
F(kHz)
10
8
6
4
2
0
UT 19:47 19:48 19:49 19:50 19:51 19:52 19:53
INV 66.7 68.7 70.7 72.7 74.7 76.6 78.6
F(kHz)
10
8
6
4
2
0
UT 19:54 19:55 19:56 19:57 19:58
INV 80.5 82.4 84.2 85.9 87.2
ORBIT 3820
JUN. 18, 1969
12.6 MLT
MAGNETIC

Figure 12

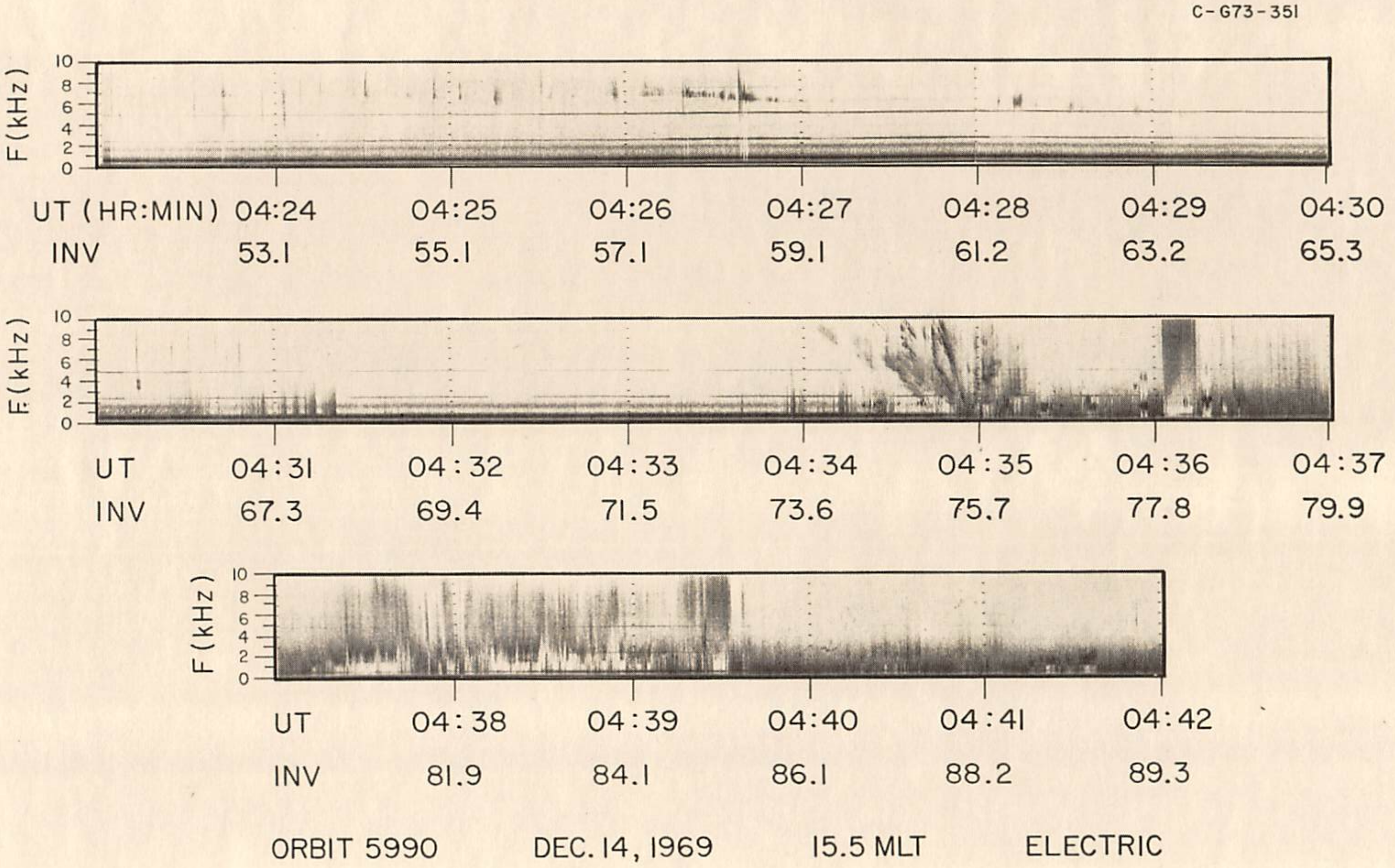
C-G73-351
F(kHz)
0
2
4
6
8
10
UT (HR:MIN) 04:24 04:25 04:26 04:27 04:28 04:29 04:30
INV 53.1 55.1 57.1 59.1 61.2 63.2 65.3
UT 04:31 04:32 04:33 04:34 04:35 04:36 04:37
INV 67.3 69.4 71.5 73.6 75.7 77.8 79.9
UT 04:38 04:39 04:40 04:41 04:42
INV 81.9 84.1 86.1 88.2 89.3
ORBIT 5990
DEC. 14, 1969
15.5 MLT
ELECTRIC

Figure 13

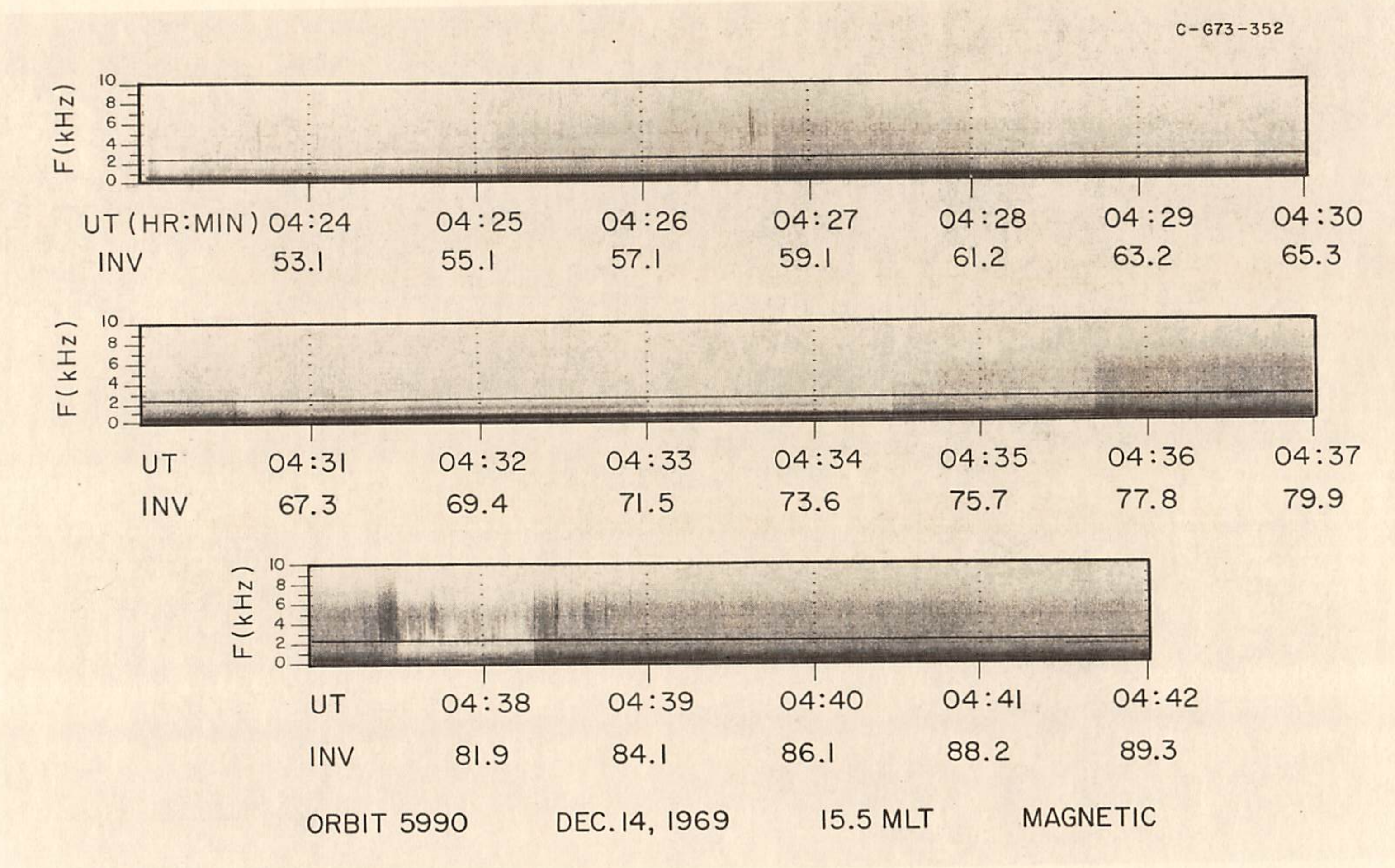
C-G73-352
F(kHz)
10
8
6
4
2
0
UT (HR:MIN) 04:24 04:25 04:26 04:27 04:28 04:29 04:30
INV 53.1 55.1 57.1 59.1 61.2 63.2 65.3
UT 04:31 04:32 04:33 04:34 04:35 04:36 04:37
INV 67.3 69.4 71.5 73.6 75.7 77.8 79.9
UT 04:38 04:39 04:40 04:41 04:42
INV 81.9 84.1 86.1 88.2 89.3
ORBIT 5990
DEC. 14, 1969
15.5 MLT
MAGNETIC

Figure 14

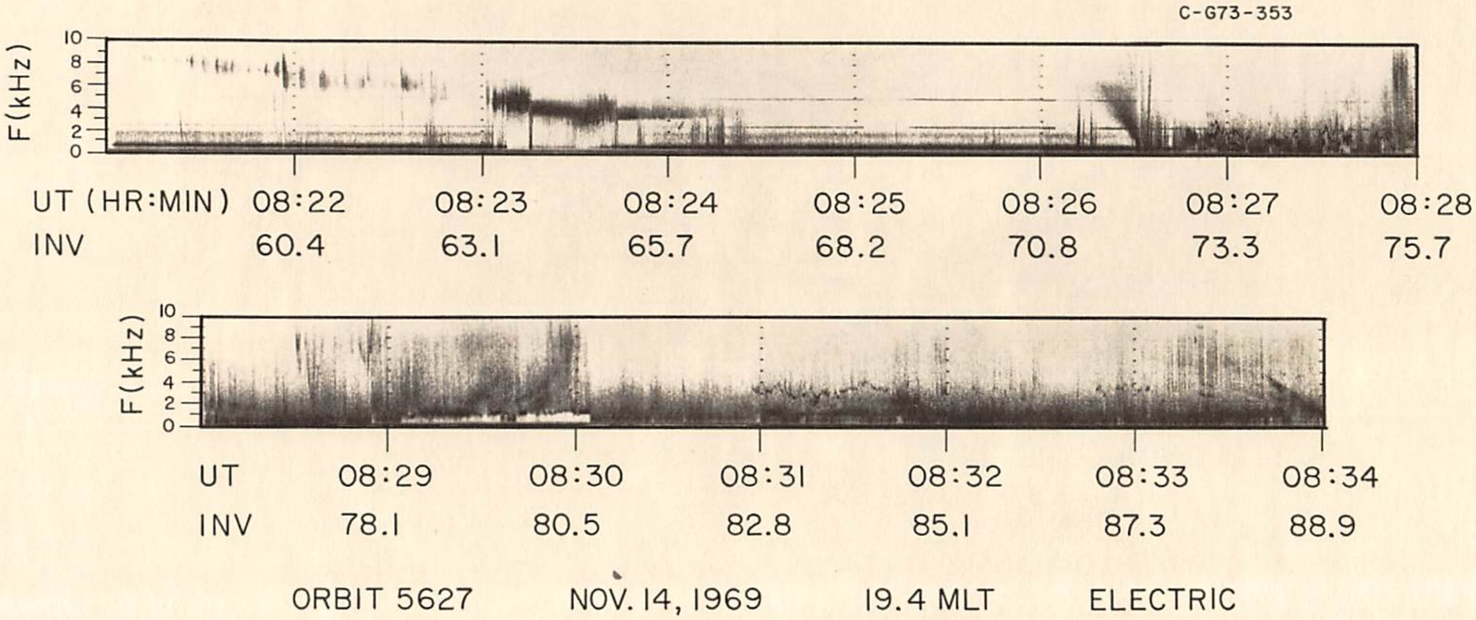
C-G73-353
F(kHz)
10
8
6
4
2
0
UT (HR:MIN) 08:22 08:23 08:24 08:25 08:26 08:27 08:28
INV 60.4 63.1 65.7 68.2 70.8 73.3 75.7
F(kHz)
10
8
6
4
2
0
UT 08:29 08:30 08:31 08:32 08:33 08:34
INV 78.1 80.5 82.8 85.1 87.3 88.9
ORBIT 5627
NOV. 14, 1969
19.4 MLT
ELECTRIC

Figure 15

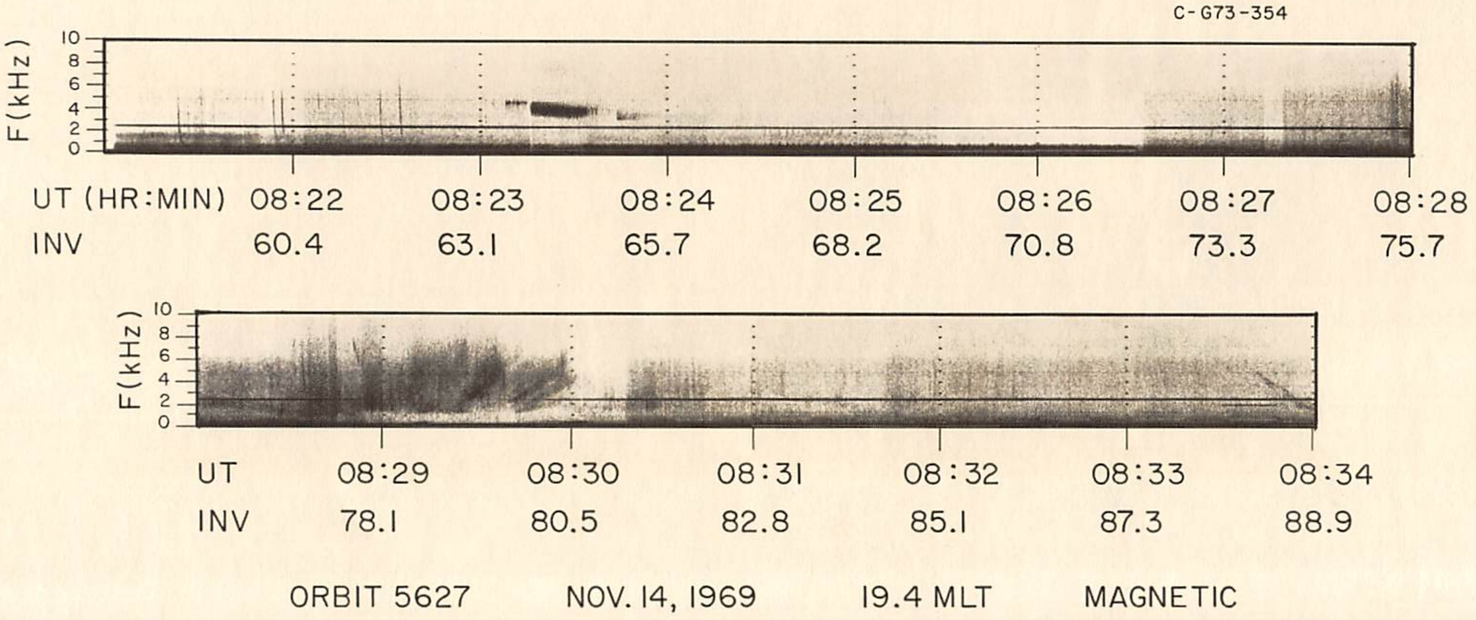
C-G73-354
F(kHz)
10
8
6
4
2
0
UT (HR:MIN)
08:22
08:23
08:24
08:25
08:26
08:27
08:28
INV
60.4
63.1
65.7
68.2
70.8
73.3
75.7
F(kHz)
10
8
6
4
2
0
UT
08:29
08:30
08:31
08:32
08:33
08:34
INV
78.1
80.5
82.8
85.1
87.3
88.9
ORBIT 5627
NOV. 14, 1969
19.4 MLT
MAGNETIC

Figure 16

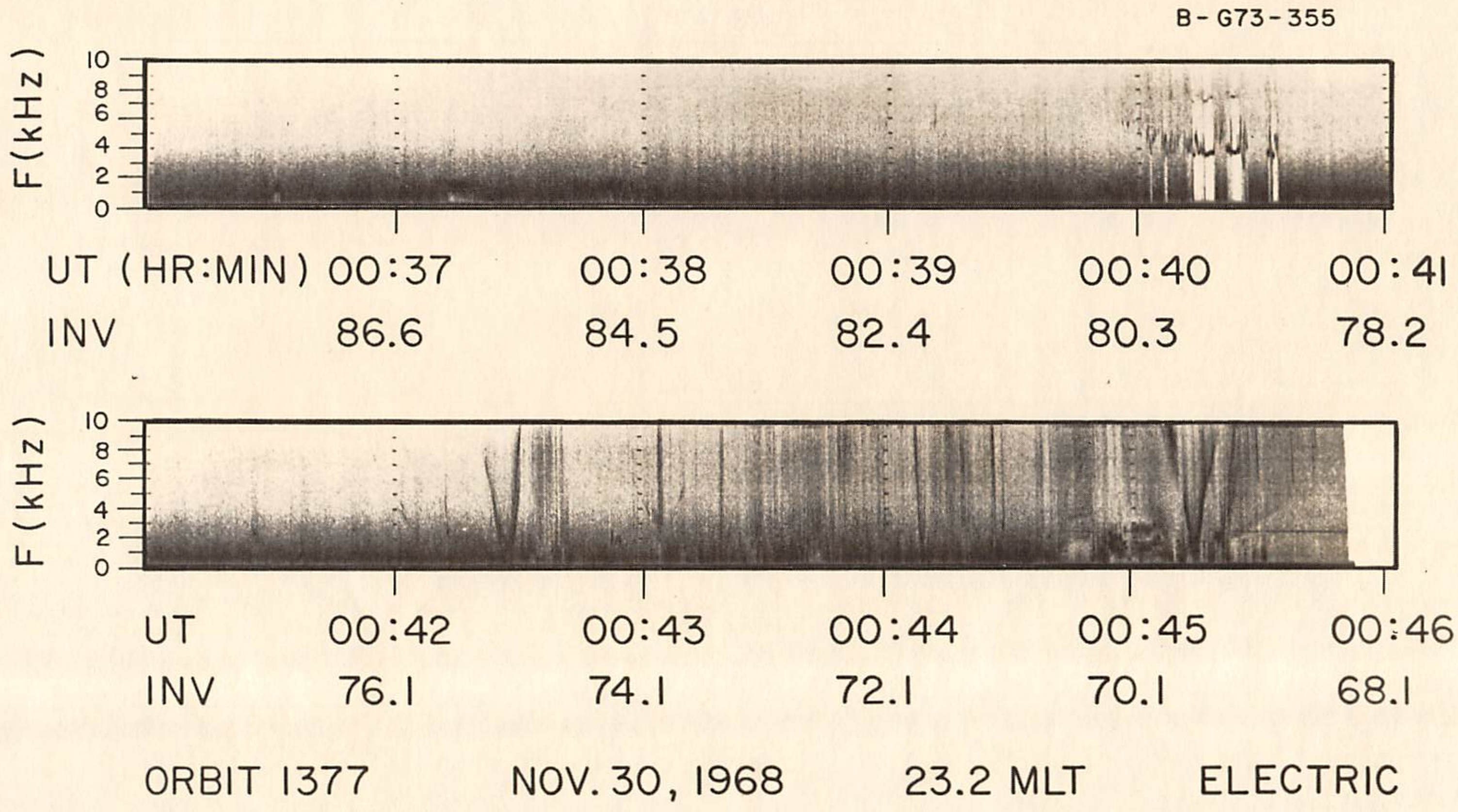
B-G73-355
F(kHz)
10
8
6
4
2
0
UT (HR:MIN) 00:37 00:38 00:39 00:40 00:41
INV 86.6 84.5 82.4 80.3 78.2
F(kHz)
10
8
6
4
2
0
UT 00:42 00:43 00:44 00:45 00:46
INV 76.1 74.1 72.1 70.1 68.1
ORBIT 1377 NOV. 30, 1968 23.2 MLT ELECTRIC

Figure 17

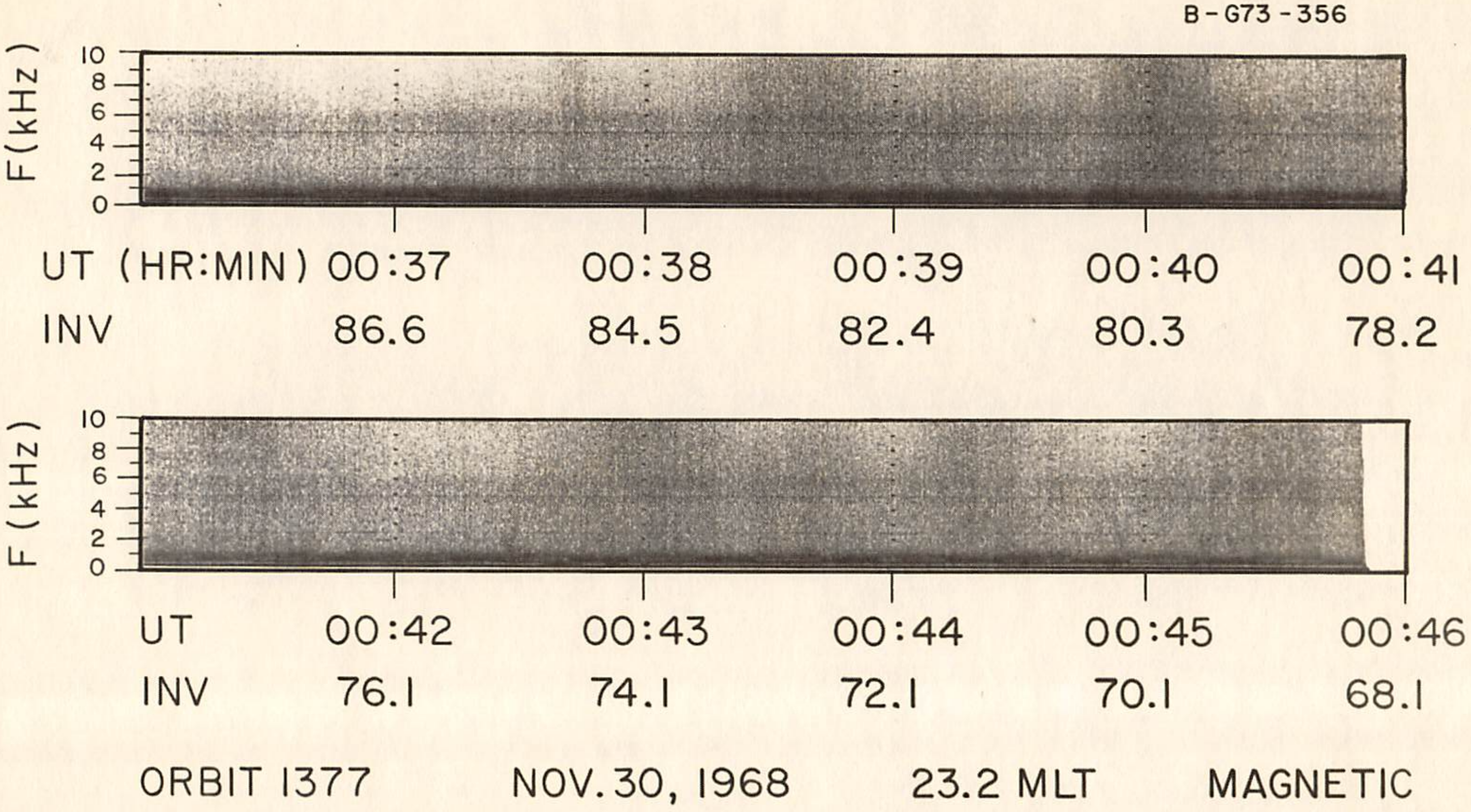
B-G73-356
F(kHz)
10
8
6
4
2
0
UT (HR:MIN) 00:37 00:38 00:39 00:40 00:41
INV 86.6 84.5 82.4 80.3 78.2
F (kHz)
10
8
6
4
2
0
UT 00:42 00:43 00:44 00:45 00:46
INV 76.1 74.1 72.1 70.1 68.1
ORBIT 1377 NOV. 30, 1968 23.2 MLT MAGNETIC

Figure 18

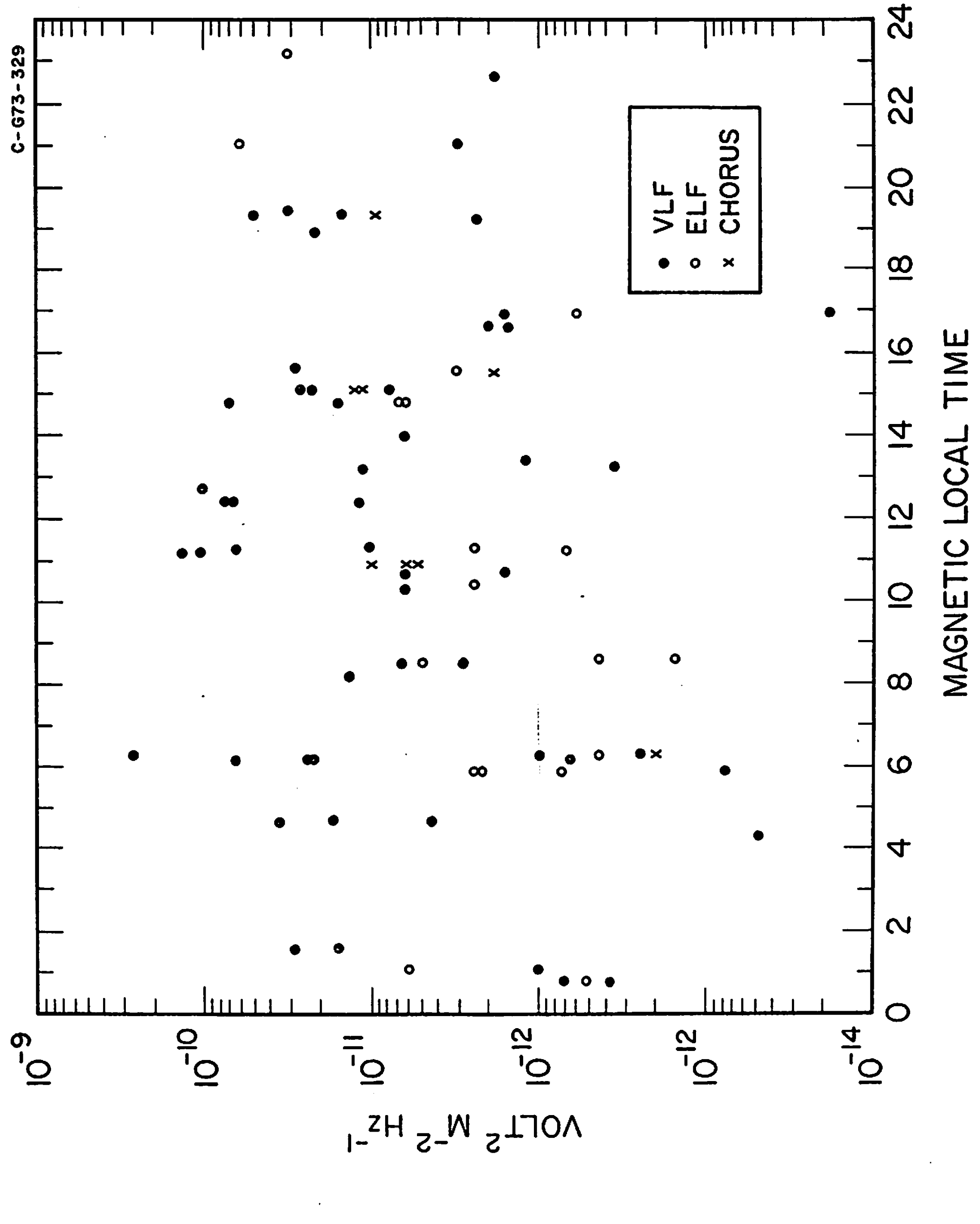
C-G73-329
● VLF
○ ELF
× CHORUS
0
2
4
6
8
10
12
14
16
18
20
22
24
MAGNETIC LOCAL TIME
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-12}
10^{-14}
VOLT^2 M^{-2} Hz^{-1}

Figure 19

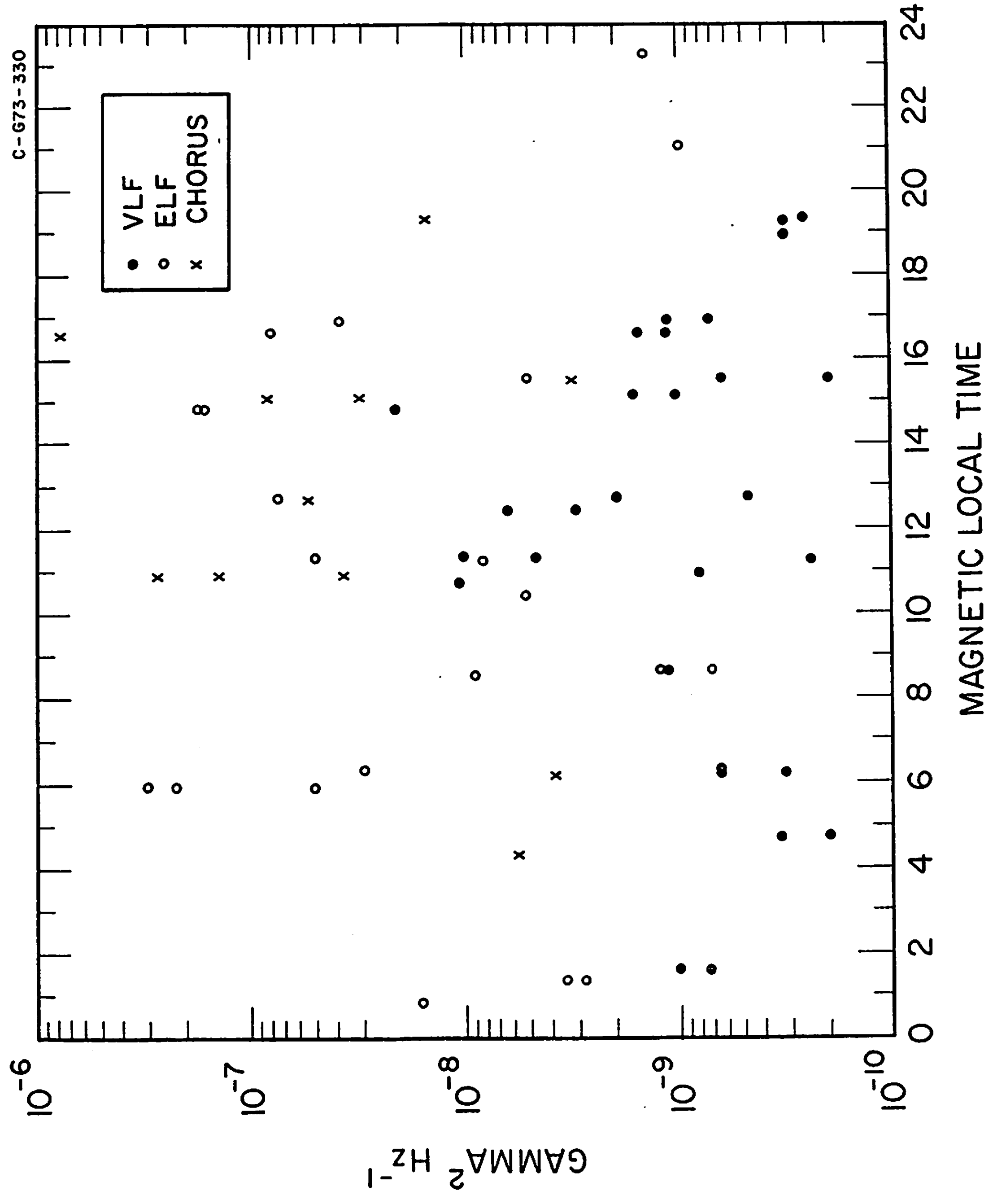
C-G73-330
● VLF
○ ELF
× CHORUS
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
GAMMA^2 Hz^{-1}
0
2
4
6
8
10
12
14
16
18
20
22
24
MAGNETIC LOCAL TIME

Figure 20