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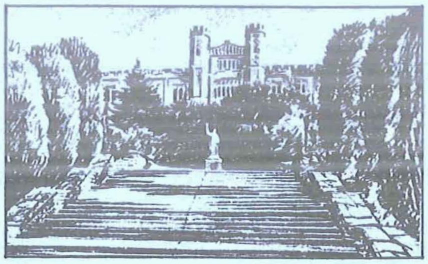

XAVIER UNIVERSITY

DEPARTMENT OF PHYSICS

RESEARCH REPORT

OBSERVATIONS ON PULSATING AURORAS

by

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OBSERVATIONS ON PULSATING AURORAS[+]

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ABSTRACT

Optical auroral pulsations in λ3914 N_2^+ and λ5577 OI have been measured in the frequency range 0.01 to 1.0 Hertz by a double photometer system during the NASA Airborne Auroral Expedition. The spectral density calculations invariably show a pronounced peak in the 0.05 to 0.2 frequency range. The pulsating forms were confined to the region between 62° and 69° North latitude. No pulsations were detectable in the λ4861 Hβ emission.

INTRODUCTION

This paper is concerned with the measurement of pulsations in the auroral luminosity during the NASA Airborne Expedition 19 January to 6 February, 1968. This expedition, based at Fort Churchill, Manitoba, consisted of the coordinated experiments of groups from nine universities and research institutions aboard the NASA Convair 990 jet aircraft.

Auroral pulsations have been observed by Campbell and Rees (1961) and by Paulson and Shepard (1966) using photo-electric photometers, and more recently by Cresswell and Davis (1966) using an image orthicon television system. The pulsations are quasi-periodic and usually appear only as a slight modulation of the total luminosity. The pulsations are often connected with quiet forms and represent a fairly stationary phenomenon in contrast to rapid and complex motions associated with the break-up phase of an auroral display. Their cause is unknown, but it seems likely that they reflect oscillations either in the particle source or in the magnetospheric conditions along the path of the particles. Thus a knowledge of the frequencies and intensities of these fluctuations could be of importance in formulating a complete auroral theory.

INSTRUMENTATION

The auroral luminosity was observed through an optical window in the roof of the aircraft using two identical photometers which were precisely aligned so as to view identical regions. Each photometer consisted of an f/5 three-inch diameter coated acromat, field lens, interchangeable two-inch diameter interference filter, variable diaphragm, and a reflecting cone light pipe which coupled the interference filter to the one-inch diameter cathode of an EMR photomultiplier. This light pipe increased the sensitivity by almost a factor of four without the increase in dark current which would have resulted from using a larger diameter cathode. With this design and the use of high quality electronics, the sensitivity for recording pulsations was limited only by the statistical photon noise. The narrow-band interference filters were chosen to measure λ4861 Hß, λ5577 OI, or λ3914 N_2^+ auroral emissions.

All data were recorded simultaneously on strip chart and magnetic tape recorders.

Regular photometric calibrations were carried out using a standard tungsten lamp and a C^{14} radioactive light source (courtesy of R. H. Eather).

All measurements were obtained during quiet magnetic periods with K_p values in the range of $0 - 3^-$. The auroral absorption at 20 and 30 MHz was simultaneously measured aboard the aircraft by Bradbury and Joki (1969) and found to be less than 1 db during all the recorded periods of pulsation.

DATA ANALYSIS

Records of the aircraft's stability show that the roll motion about the longitudinal axis occasionally had an amplitude as large as one degree peak-to-peak. This 4.6 sec periodic oscillation was discernible in only two of the pulsation records.

All suitable records were digitized using the Nyquist or Shannon criterion of sampling so as to avoid any possible aliasing error. Assuming that the fluctuations in time of auroral brightness constitute a physical realization of a second-order stationary process, the power spectral densities were computed using the discrete Fourier transform algorithm of Cooley and Tukey (1965) followed by a Hanning smoothing procedure (Blackman and Tukey, 1958).

Figure 1 shows a portion of the λ5577 OI intensity versus time record for a very vivid and somewhat oval shaped patch of strongly pulsating aurora that was recorded while flying at an altitude of 33,000 feet at geomagnetic coordinates 62° 41' N latitude and 38° 01' W longitude (20d, 3 hrs, 57 min, UT). This even lasted for slightly over four minutes and was unusual in that the fluctuations were often 100 percent of the total intensity. A visual inspection of the record indicated that it was divided into four sections. The first three (lengths of 78, 68, and 58 seconds, respectively) were separated from each other by 10 sec. periods of constant intensity, after which the pulsation frequencies appreciably increased (30 to 60 percent). The fourth section was distinguished from the third only by an abrupt increase in frequency that lasted for only 18 seconds. The prominent frequencies of the pulsations and their relative increase with time can be seen in Figure 2 where the spectral densities for each of the four sections are given as a function of frequency.

It is impossible to know from these observations whether the frequency spectrum, such as shown in Figure 2, is actually that of a single pulsating form or the sum of several that lie in the field of view. However, Cresswell and Davis (1966) have shown, using an image orthicon television system, that whereas the pulsation of an individual form is observed to be everywhere in phase (within the instrumental field of view), adjacent portions of the sky are observed to pulsate independently.

Figure 3 shows a portion of the original record of the λ4861 Hß and λ3914 N_2^+ intensities for a subvisual aurora obtained at geomagnetic coordinates 65° 27' N latitude and 37° 34' W longitude (37d, 10 hrs, 38 min, UT). The λ3914 N_2^+ radiation consisted of approximately a 25 percent modulation of the 200 Rayleigh average intensity. The computed spectral densities for various portions of the 12 minutes duration of the pulsations showed that the frequency composition changed only slightly with time and that this aurora had more power in the higher frequencies (greater than 0.3 Hertz) than that of Figure 2.

During this expedition the λ4861 Hß was simultaneously measured and recorded, as shown in Figure 3, along with either λ5577 OI or λ3914 N_2^+ emissions. The very small variations in the Hß signal are completely random and are the result of statistical photon noise. An analysis of the entire collected data indicates a total absence of Hß fluctuations at least to the limit of detection of about 0.2 Rayleigh. This indicates that the pulsations were due entirely to electron excitation.

It should be pointed out that considerable care must be exercised in calculating and interpreting power spectral densities of auroral radiation since a change in phase of the fluctuations can result in the appearance of strong higher harmonics that, in fact, have no physical reality. Another common fault is the attempt to give a physical interpretation to the approximately exponentially decreasing spectral density with increasing frequency, since this can be the result of taking a discrete Fourier transform of a finite, quasi-periodic function of time.

In order to obtain the relative occurrence of the various frequencies of pulsations, the prominent frequencies were taken from the spectral density plots for all fluctuating auroras recorded during the expedition. The result is shown by the histogram in Figure 4 where a frequency interval of 0.05 Hertz was chosen since this is the approximate resolution of the spectral density calculations. The plot shows a broad maximum in the 0.05 to 0.2 Hertz region with a peak at the 0.05 to 0.1 Hertz interval.

An analysis of all auroras observed during this expedition shows that pulsating forms occurred between north geomagnetic latitudes of 62^{o} and 69^{o} and that their maximum occurrence is in the few hours following local geomagnetic midnight.

ACKNOWLEDGMENTS

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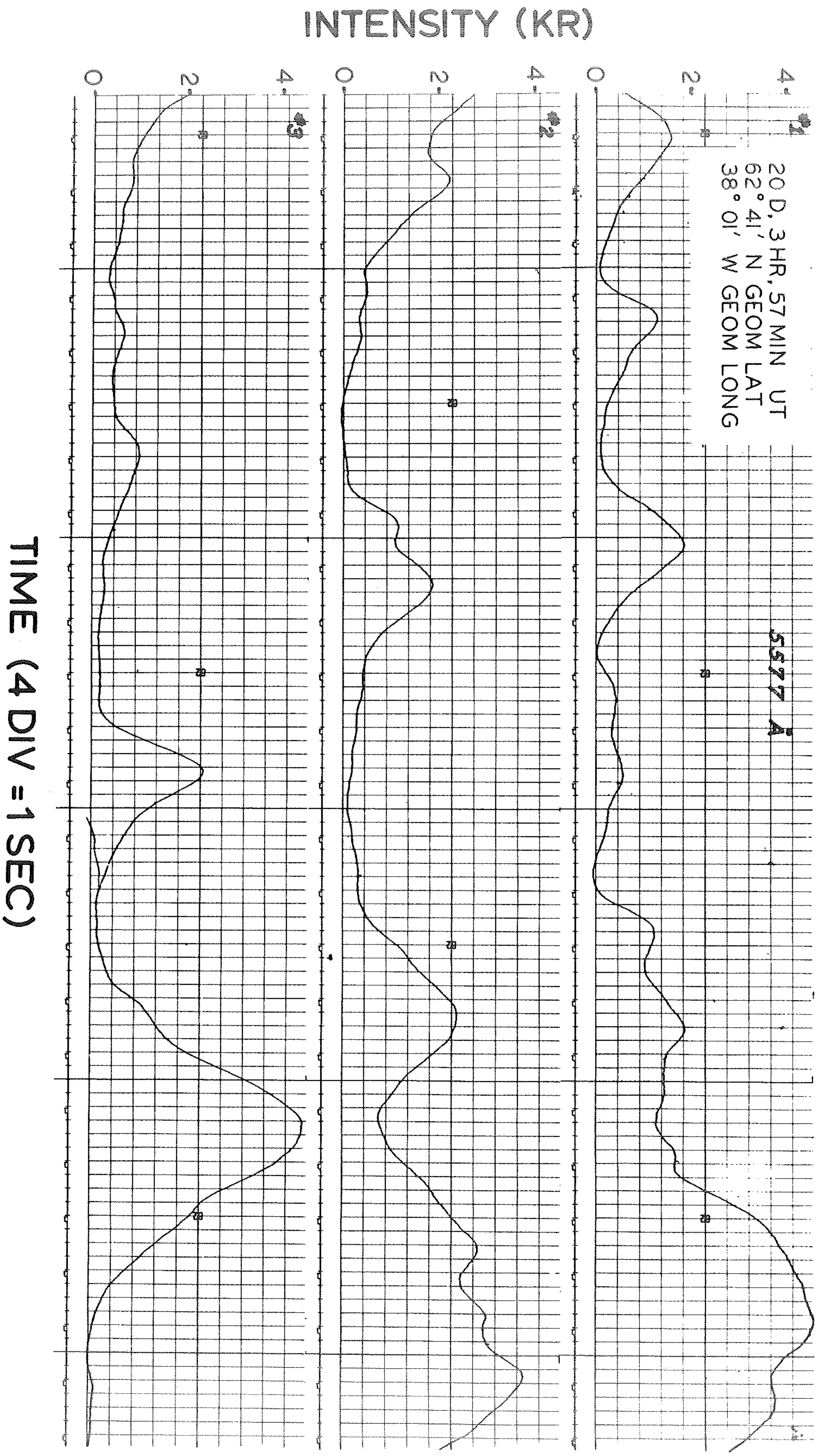
FIGURE CAPTIONS

1. Part of the original record of the λ5577 OI radiation of a very strongly pulsating aurora.

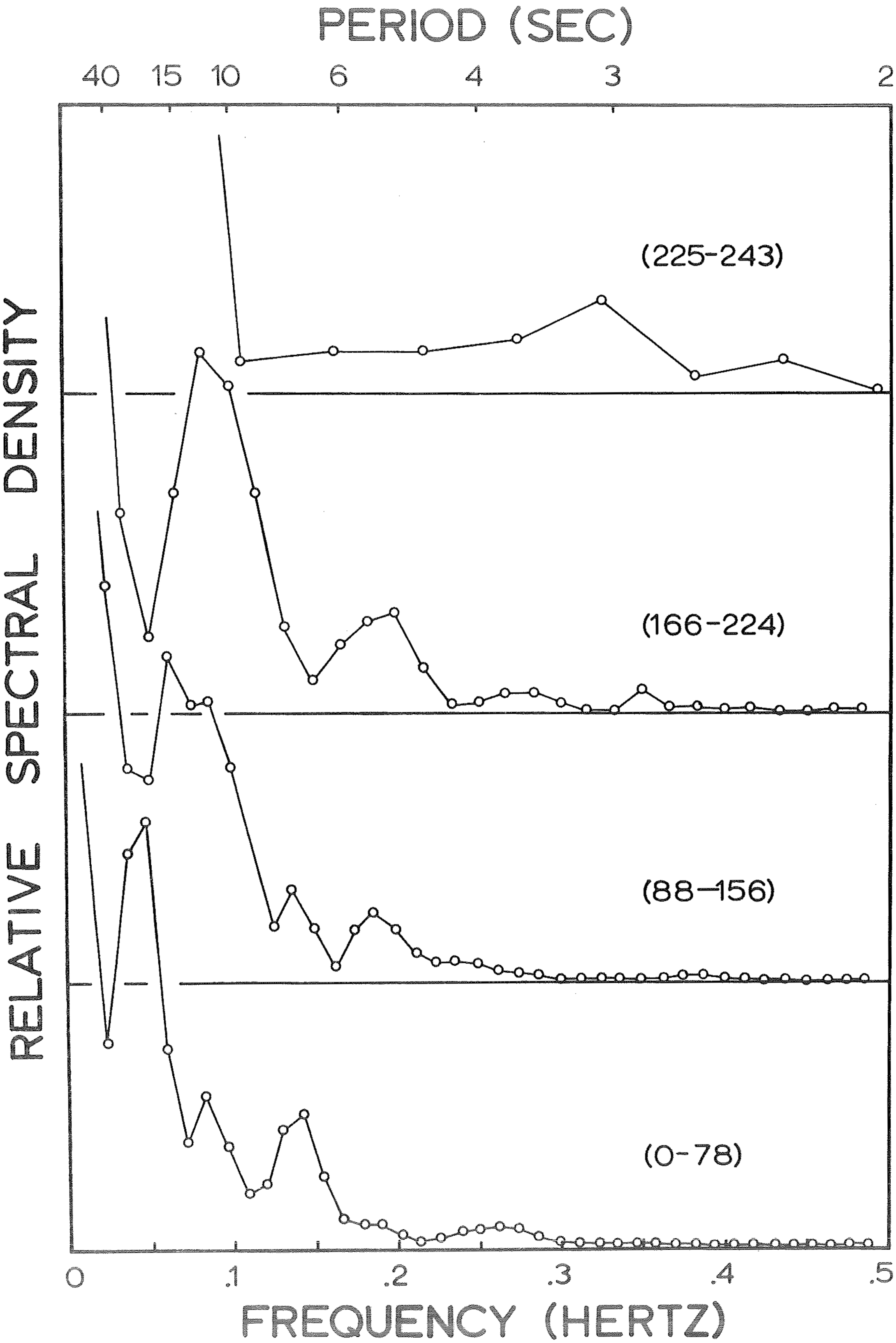
2. The power spectral density of four consecutive auroral brightness fluctuation records of λ5577 OI radiation obtained 20d, 3 hr, 57m, UT and 62° 41' N. Geom. Lat. and 38° 01' W Geom. Long.

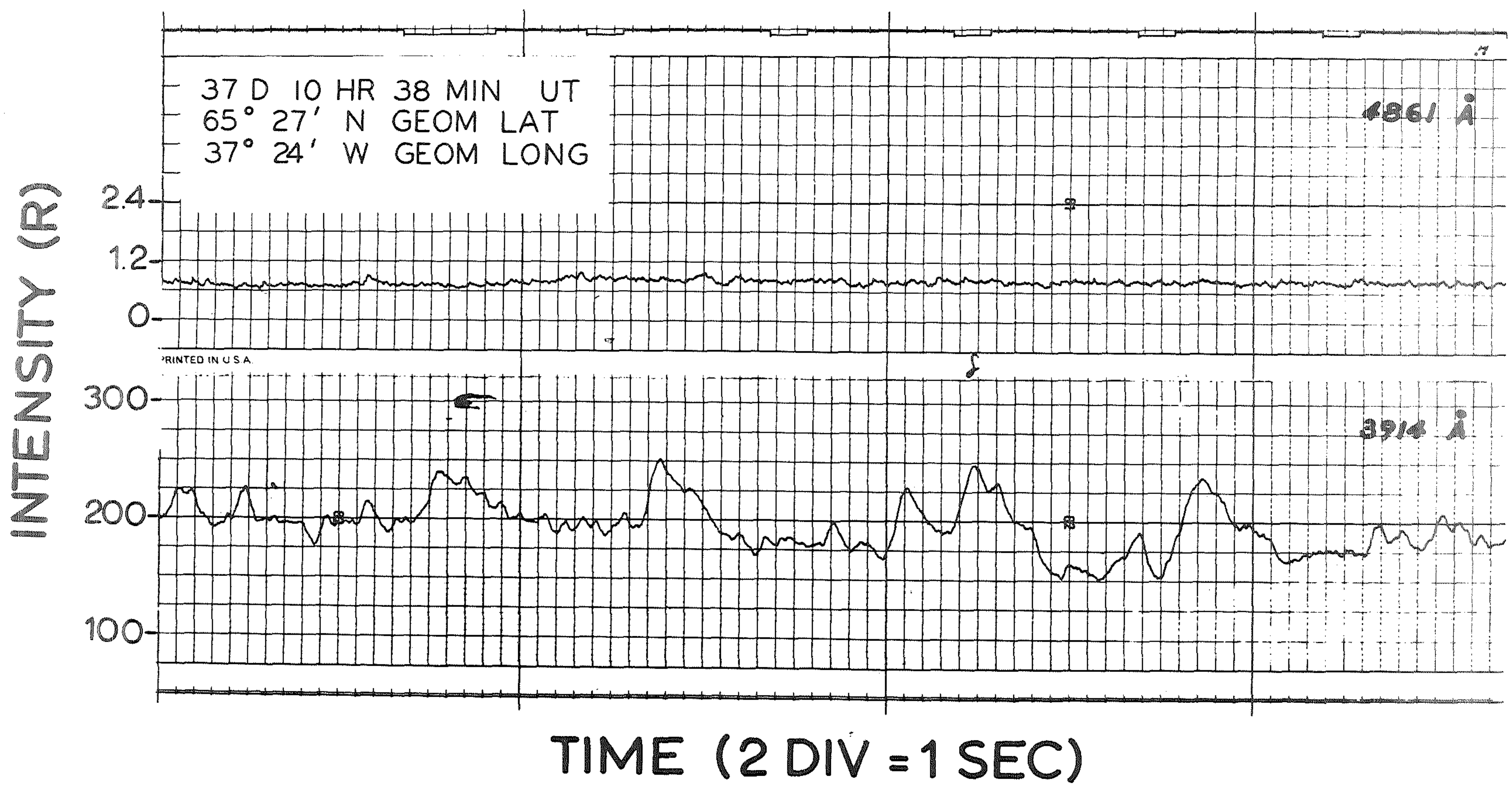
3. Simultaneous recording of the λ4861 Hβ and λ3914 N_2^+ radiations from a pulsating aurora.

4. The relative occurrence of the various frequencies of pulsations for all fluctuating auroras recorded during the expedition.

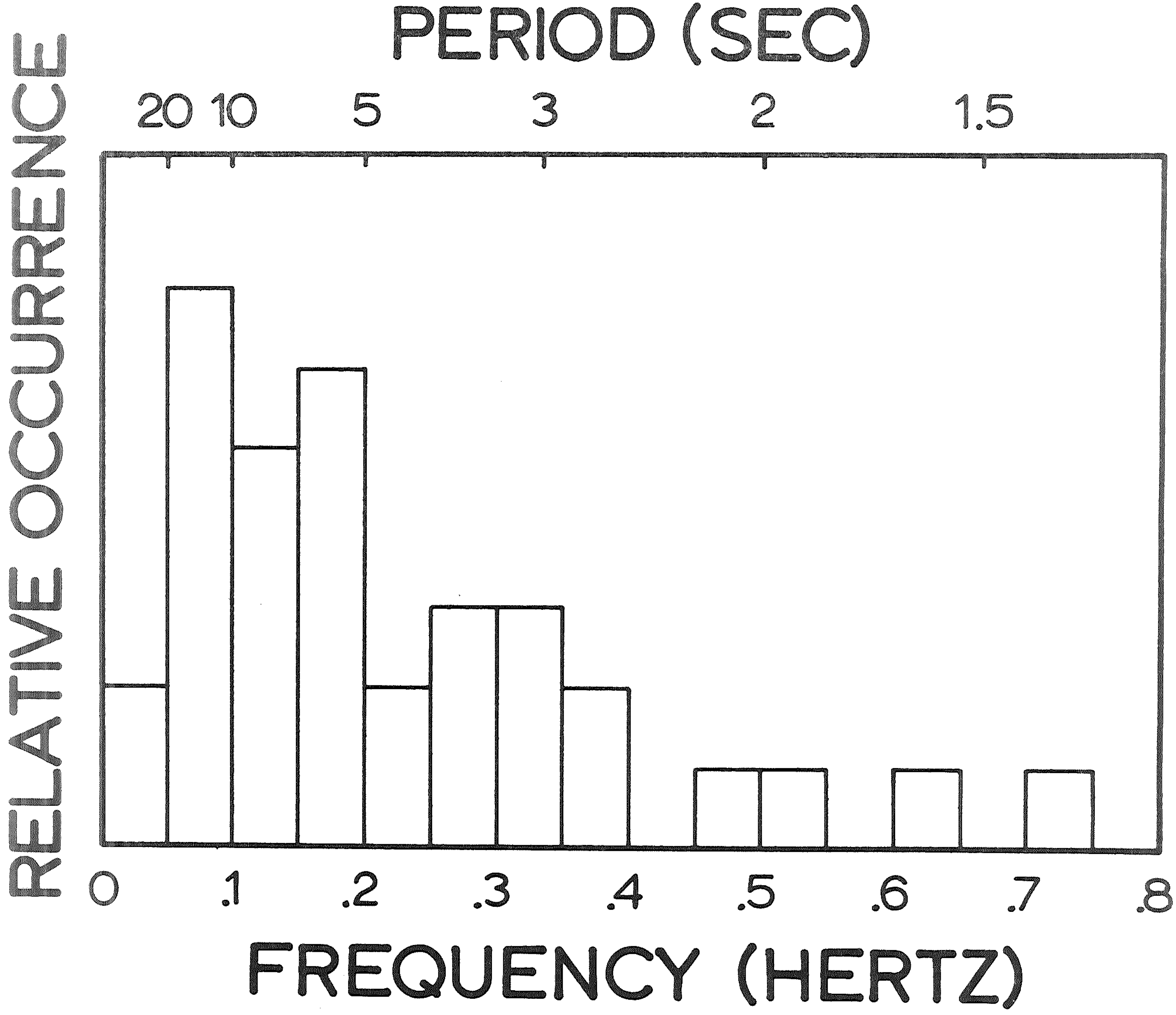


INTENSITY (KR)
0
2
4
#1
#2
#3
20 D, 3 HR, 57 MIN UT
62° 41' N GEOM LAT
38° 01' W GEOM LONG
5577 Å
TIME (4 DIV = 1 SEC)


PERIOD (SEC)
40 15 10 6 4 3 2
(225-243)
(166-224)
(88-156)
(0-78)
RELATIVE SPECTRAL DENSITY
0 .1 .2 .3 .4 .5
FREQUENCY (HERTZ)



37 D 10 HR 38 MIN UT
65° 27′ N GEOM LAT
37° 24′ W GEOM LONG
INTENSITY (R)
2.4
1.2
0
300
200
100
4861 Å
3914 Å
PRINTED IN U.S.A.
TIME (2 DIV = 1 SEC)


PERIOD (SEC)
20 10 5 3 2 1.5
RELATIVE OCCURRENCE
0 .1 .2 .3 .4 .5 .6 .7 .8
FREQUENCY (HERTZ)