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LOW INTENSITY DECAMETER EMISSIONS FROM JUPITER

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ABSTRACT

33720

Observations of Jupiter with the 26.3 Mc/s Christiansen-type array of the Clark Lake Radio Observatory have been analyzed with a view towards the determination of how the noise storm morphology might be altered when very weak activity (flux $< 10^{-23}$ w/m^2/cps) is included. Analysis of the distribution of activity with system III central meridian longitude shows the same general shape as reported by other workers. Although the occurrence-probability histogram peaks are somewhat broadened in comparison to other less sensitive surveys in this frequency range, the region from 330° to 45° longitude still appears completely void of activity. Analysis of the intensity distribution at 26.3 Mc/s suggests two components of the emission. One component is comprised of a large amount of weak activity of flux density between 10^{-23} and 10^{-22} w/m^2/cps. The other, secondary component is comprised of strong activity of flux density greater than 7×10^{-22} w/m^2/cps and may correspond to the radiation commonly observed by workers at lower frequencies.

Author

LOW INTENSITY DECAMETER EMISSIONS FROM JUPITER

During September and October, 1963, and February and March, 1964, the 26.3 Mc/s radiation from Jupiter was systematically observed with the University of Maryland decametric antenna at Clark Lake, California. In view of the particularly high sensitivity of this instrument ($<5 \times 10^{-24}$ w/m^2/cps) special attention was given to the determination of how the apparent properties of the Jovian decameter radiation might be modified by the ability to detect emission considerably weaker than that observed by most other workers. A report of the results of this study follows.*

The antenna is a Christiansen-type array consisting of 8 elements spaced at intervals along a two-mile E-W base line. Each element is an N-S colinear array of 19 full-wave dipoles. The response pattern of the array is multilobed -- the individual lobes having half-power widths of 10'E-W by 3°N-S and E-W spacing of 1.5°. The declination of the response pattern can be set between 3°N and 63°N by adjusting the phase difference between the individual dipoles of the array. Therefore as a discrete radio source moves across the sky at sidereal rate it passes through one of the lobes of the grating response every six minutes. This feature simplifies identification of the emission since the times at which activity from the planet is detected must correspond to the passage of the source

* A preliminary report of the 1963 observations will be published in The Astrophysical Journal, July 1, 1964.

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across one of the lobes of the response pattern. We note in this regard that the average difference between the observed and calculated lobe crossing times was about ± 18 sec. which corresponds to apparent angular shifts in right ascension of about 4'. Since ionospheric refraction normally causes position shifts of this order in the case of "radio star" observations, we can say that within the limits of our system the noise storm did indeed originate at the planet. A typical record of a Jovian noise storm is shown in Figure 1.

The receiving system is a Ryle-Vonberg radiometer having an integration time of 2 sec. The receiver bandwidth was 35 kc/s during the 1963 observations and 800 kc/s during the 1964 observing period.

The 1963 observations were made nightly from September 19 to October 11, inclusive, with an average observing time of 3.3^h per night. Since meridian transit occurred between 00^h and 02^h local time, the observations were free from interference due to solar noise, and man-made interference was at a minimum. The 1964 data were collected between February 13 and March 14, inclusive, with an average daily observing time of 2.5^h. Jupiter was near conjunction during this period, and hence, meridian transit occurred in mid-afternoon. As a result, interference from communications traffic and occasional solar noise reduced the total number of daily observations acceptable for analysis to 17.

The variation of the 26.3 Mc/s noise storm activity with system III central meridian longitude is shown in Figure 2. The histogram gives the longitudinal distribution of occurrence probability which is found by taking the ratio of the number of times Jupiter activity was observed to the number of times the planet passed one of the lobes of the grating response for each 10° longitude interval. Although the observations may not be sufficient to insure that the data are statistically complete one can still distinguish the three regions discussed by Douglas (1960): Region 1, 70° to 190°, Region 2, 190° to 265°, and Region 3, 265° to 330°. The distribution of total observations with longitude plotted in Figure 3 serves to show that at least all longitudes were nearly equally sampled during the study. One notices that the probability histogram peaks of Figure 2 are somewhat broadened in comparison to the results of other workers who have found the peaks grow narrower toward higher frequencies. In confirmation of a suggestion by Barrow (1962), it appears that detection of activity at all longitudes within the three main regions only requires sufficient sensitivity at the higher frequancies. On the other hand, this result does not lend support to a theoretical prediction by Ellis and McCulloch (1963) that the 26 Mc/s histogram peaks should be confined to narrow longitude hands. The significance of weak emission will be discussed in more detail later.

It is significant that the quadrant from 330° to 40° is completely void of activity. Although some workers have reported observing a few weak bursts in this region, especially below 18 Mc/s, Douglas and Smith (1963) report that the Yale workers have never detected storms at 22.2 Mc/s having flux greater than 10^{-21} w/m^{2}/cps between longitudes 350° and 70°. In the case of our observations, no activity of flux greater than 5×10^{-24} w/m^{2}/cps was detected. (On only one occasion did we observe any activity below 70° longitude.) All flux measurements were made relative to the discrete source Hercules A (3C 348) which has nearly the same declination as did Jupiter during these observations. The 26.3 Mc/s flux of Hercules A was taken to be 2×10^{-23} $w/m^2/cps$ (Conway, Kellermann, and Long, 1963).

One of the primary objectives of this study was to determine the number-intensity distribution of emission and to find, within instrumental limits, if there was a threshold below which activity did not occur. We must emphasize that here "activity" is defined as an abrupt increase in antenna temperature occurring at the time Jupiter transits one of the lobes of the antenna response pattern. No attempt has been made to further analyze any fine structure within the 40 seconds required for a source to drift between the half-power points of a single lobe. Furthermore, only activity detected when the planet was between the half-power points of the N-S envelope of the antenna response pattern were considered for this analysis. This condition was satisfied for an average of 1.8^h per night in 1963 and 2.5^h per day in 1964.

The histogram in the upper half of Figure 4 shows the intensity distribution for all storm activity observed in the 1963 series. One division on the abscissa corresponds to approximately 10^{-22} $w/m^2/cps$. The most striking features of this diagram are the large concentration of activity at low intensities and the secondary peak at the high intensity end of the figure. This result would suggest that at 26.3 Mc/s the Jupiter storms are composed primarily of "weak" activity (flux less than 10^{-22} $w/m^2/cps$) and a smaller amount of "strong" activity (flux greater than 7×10^{-22} $w/m^2/cps$) with only rare activity at intermediate intensities.

We examine the intensity distribution of the weak activity in more detail in the lower half of Figure 4. Now the major portion of the activity is clustered at intensities just above 10^{-23} $w/m^2/cps$ or at least two times the sensitivity of our antenna. A secondary peak appears around $9x10^{-23}$ $w/m^2/cps$.

The results of the same analysis for the 1964 data are shown in Figure 5. Again the intensity distribution of all activity observed is plotted in the upper half of the figure and the detailed distribution of activity falling in the first interval of the upper plot is shown in the lower half of the figure. As before, the data show a concentration of activity between 10^{-23} and 10^{-22} $w/m^2/cps$.

The combined results of the 1963 and 1964 measurements are given in Figure 6. The intensities of the individual events from the 1964 series were first doubled to correct for the fact that the Earth-Jupiter distance was greater by a factor of $\sqrt{2}$ than during the 1963 observations. Using the intensity distribution data of Figure 6 we may now make some general assumptions regarding the flux spectra of "typical" noise storms. Since the Florida workers (Smith, et al; 1963) have suggested that the flux density falls faster than f^{-5} as frequency, f, increases above 17 Mc/s, we shall assume a spectral index of -5.5. If the flux spectra obtained by extrapolation of the 26.3 Mc/s data to lower frequencies are indeed typical, then they offer an explanation of the fact that several observers report that the noise storms are generally well in excess of the sensitivity limits of their equipment. Taking the flux density for strong activity to be $8x10^{-22}$ $w/m^2/cps$, we find that at 18 Mc/s a flux density of about $6x10^{-21}$ $w/m^2/cps$ in rough agreement with other reports (e.g., Smith, et al; 1963). The weak activity having a 26.3 Mc/s flux density less than 10^{-22} $w/m^2/cps$, however, would not exceed $9x10^{-22}$ $w/m^2/cps$ at 18 Mc/s, and, therefore, would not be detected by many of the instruments presently used for Jupiter studies.

When the intensity distribution for all 26.3 Mc/s activity is determined separately for each of the three major longitude regions as shown in Figure 7, the same general shape is found with one interesting exception. In regions 1 and 3 the concentration of weak activity is pronounced. In the middle region, however, the weak and strong events are equally divided - each comprising 39.4% of the total activity observed. Such a result might have been expected from the fact that the greatest probability of occurrence for activity at frequencies nearer 20 Mc/s is found in region 2.

Summary

When the 26.3 Mc/s radiation from Jupiter is observed with sufficient sensitivity to detect emission as weak as $5x10^{-24}$ $w/m^2/cps$, the variation of occurrence with system III longitude is found to have the same general shape as reported by other workers. Although the occurrence probability histogram peaks are somewhat broadened in comparison to other less sensitive surveys in this frequency range, the region from 330^o to 40^o longitude still appears completely void of activity. Analysis of the intensity distribution at 26.3 Mc/s suggests two components of the emission. One component is comprised of a large amount of weak activity of flux densities between 10^{-23} and 10^{-22} $w/m^2/cps$. The other, secondary component is comprised

of strong activity of flux density greater than 7×10^{-22} $w/m^2/cps$ and may correspond to the radiation commonly observed by other workers at low frequencies. It now remains to supplement these data with further observations at 26.3 Mc/s and new observations with comparable sensitivity at lower frequencies. If the suggestion of two components to the decameter emission is supported, then one must consider the possibility of radiation in two modes, from two radiation belts, or even by two different mechanisms.

Acknowledgements

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FIGURE CAPTIONS

Figure

1. Tracing of a typical Jovian noise storm as observed with the Clark Lake array. The short arrows indicate the calculated lobe-crossing times for the optical planet.

2. Variation of 26.3 Mc/s activity occurrence with system III central meridian longitude. Arrows indicate location of the major regions at 22.2 Mc/s according to Douglas (1960) for comparison.

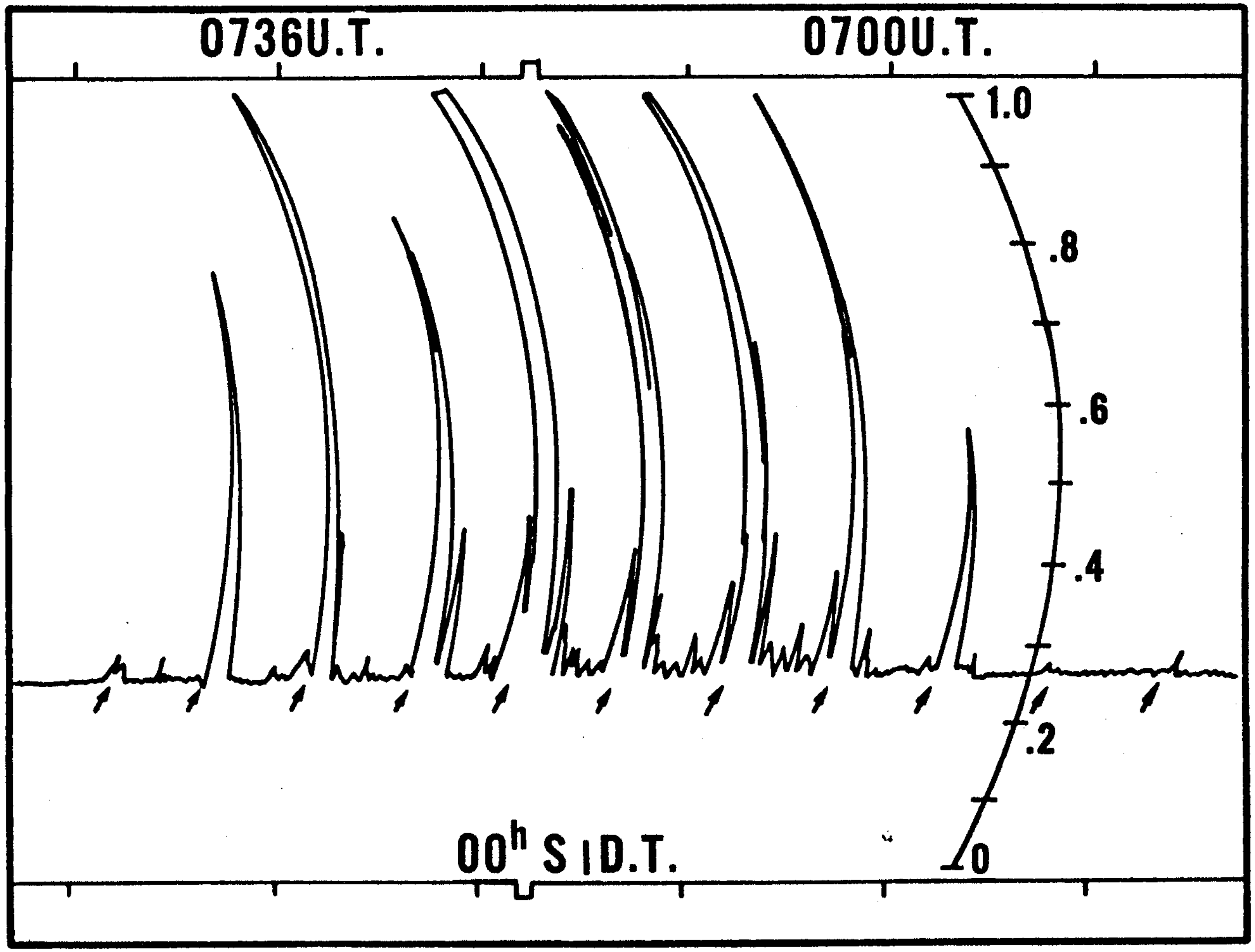
3. Longitude distribution of total observations.

4. (Upper half) Number-intensity distribution of 1963 events. (Lower half) Distribution of activity falling in first interval of upper histogram.

5. (Upper half) Number-intensity distribution of 1964 events. (Lower half) Distribution of activity falling in first interval of upper histogram.

6. (Upper half) Combined number-intensity distribution for 1963 and 1964 observations normalized to 4 A.U. (Lower half) Distribution of activity falling in first interval of upper histogram.

7. Number-intensity distribution as a function of major longitude region. (1963 and 1964 data combined.)



JUPITER, 26.3 Mc/s
SEPTEMBER 28, 1963

Figure 1.

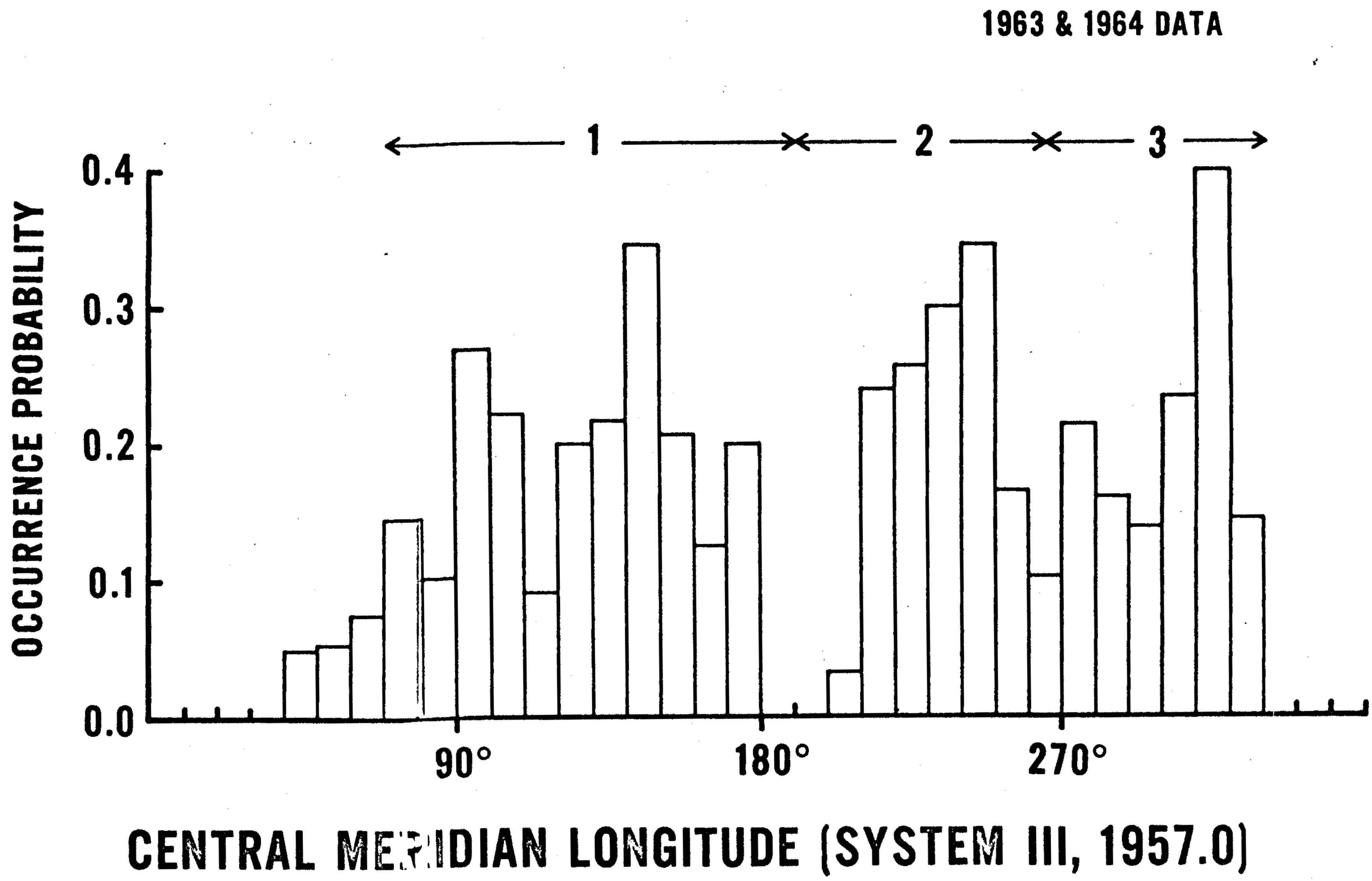

1963 & 1964 DATA
1
2
3
OCCURRENCE PROBABILITY
0.4
0.3
0.2
0.1
0.0
90°
180°
270°
CENTRAL MERIDIAN LONGITUDE (SYSTEM III, 1957.0)

Figure 2.

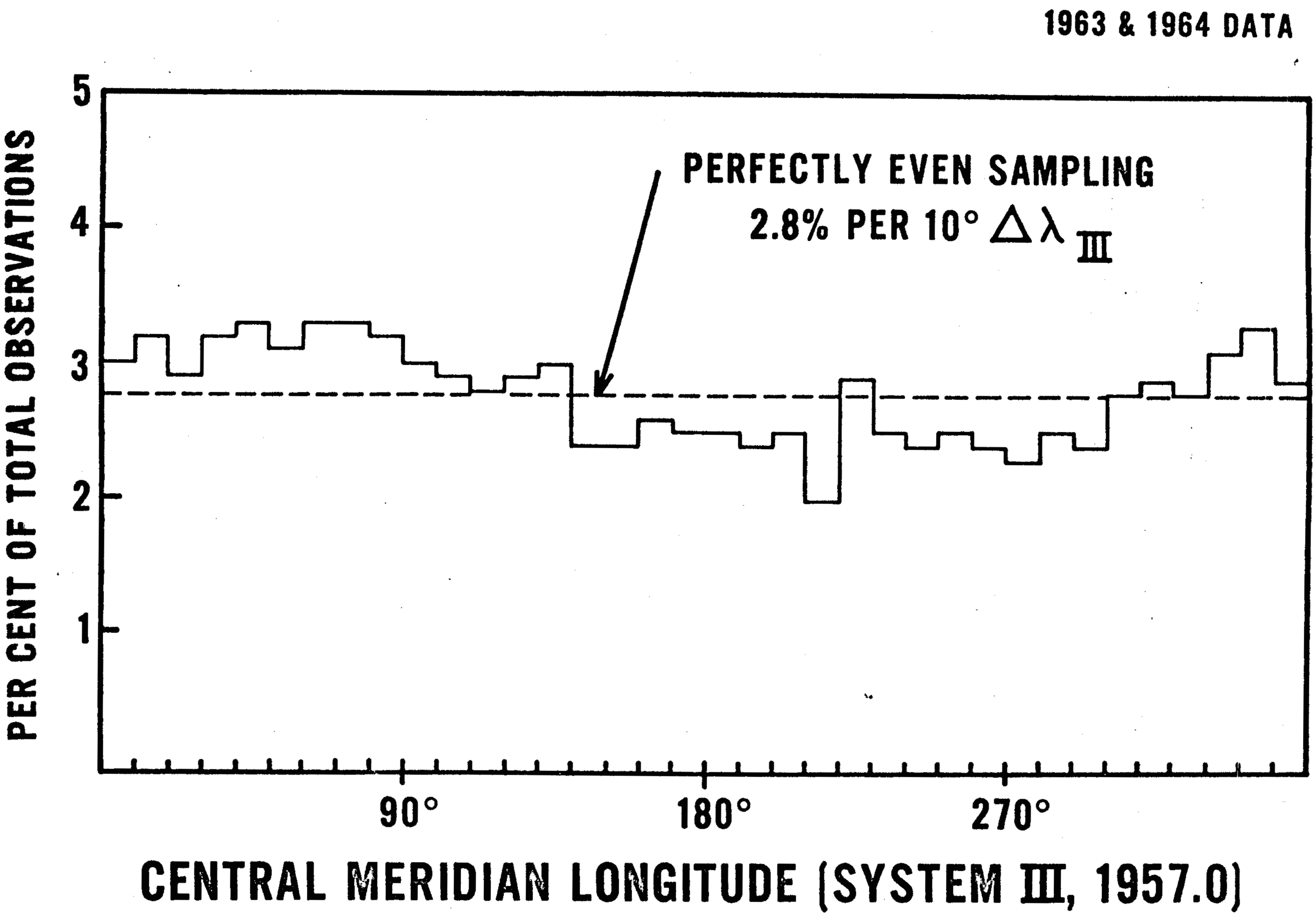

1963 & 1964 DATA
PERFECTLY EVEN SAMPLING
2.8% PER 10° $\Delta\lambda_{III}$
PER CENT OF TOTAL OBSERVATIONS
5
4
3
2
1
90°
180°
270°
CENTRAL MERIDIAN LONGITUDE (SYSTEM III, 1957.0)

Figure 3.

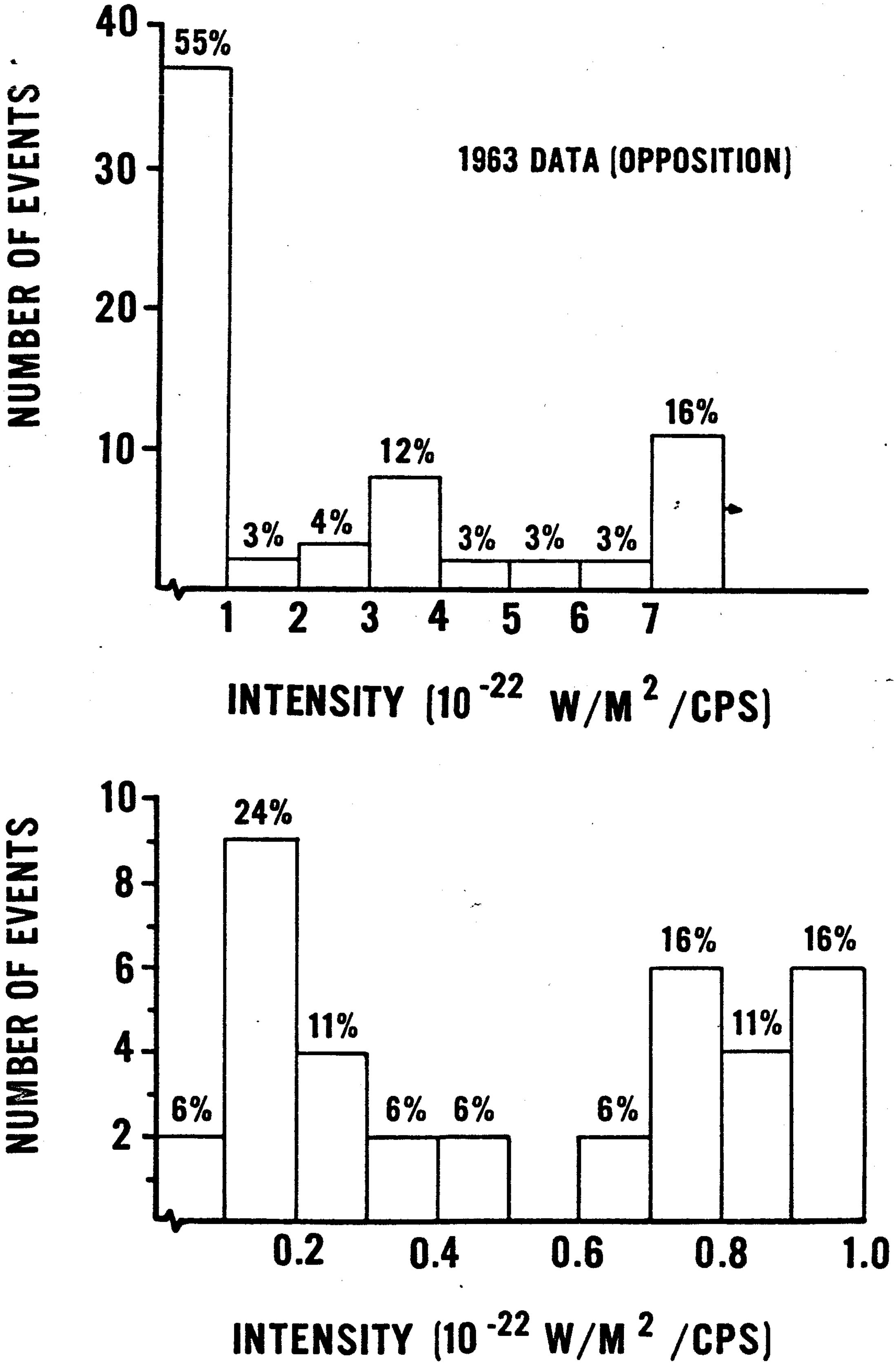

40
30
20
10
NUMBER OF EVENTS
1963 DATA (OPPOSITION)
55%
3%
4%
12%
3%
3%
3%
16%
1
2
3
4
5
6
7
INTENSITY $(10^{-22}$ $W/M^2/CPS)$
10
8
6
4
2
NUMBER OF EVENTS
6%
24%
11%
6%
6%
6%
16%
11%
16%
0.2
0.4
0.6
0.8
1.0
INTENSITY $(10^{-22}$ $W/M^2/CPS)$

Figure 4.

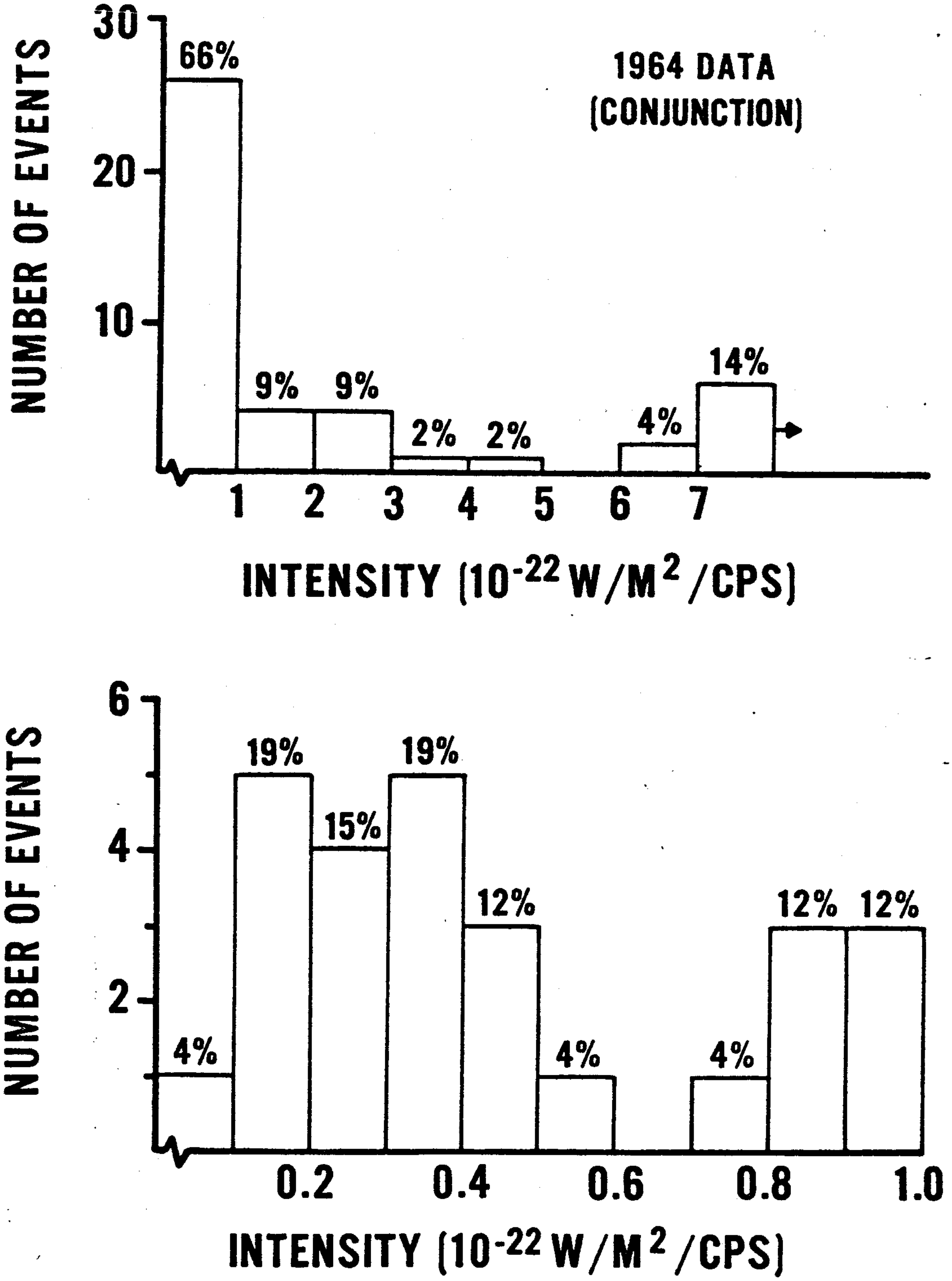
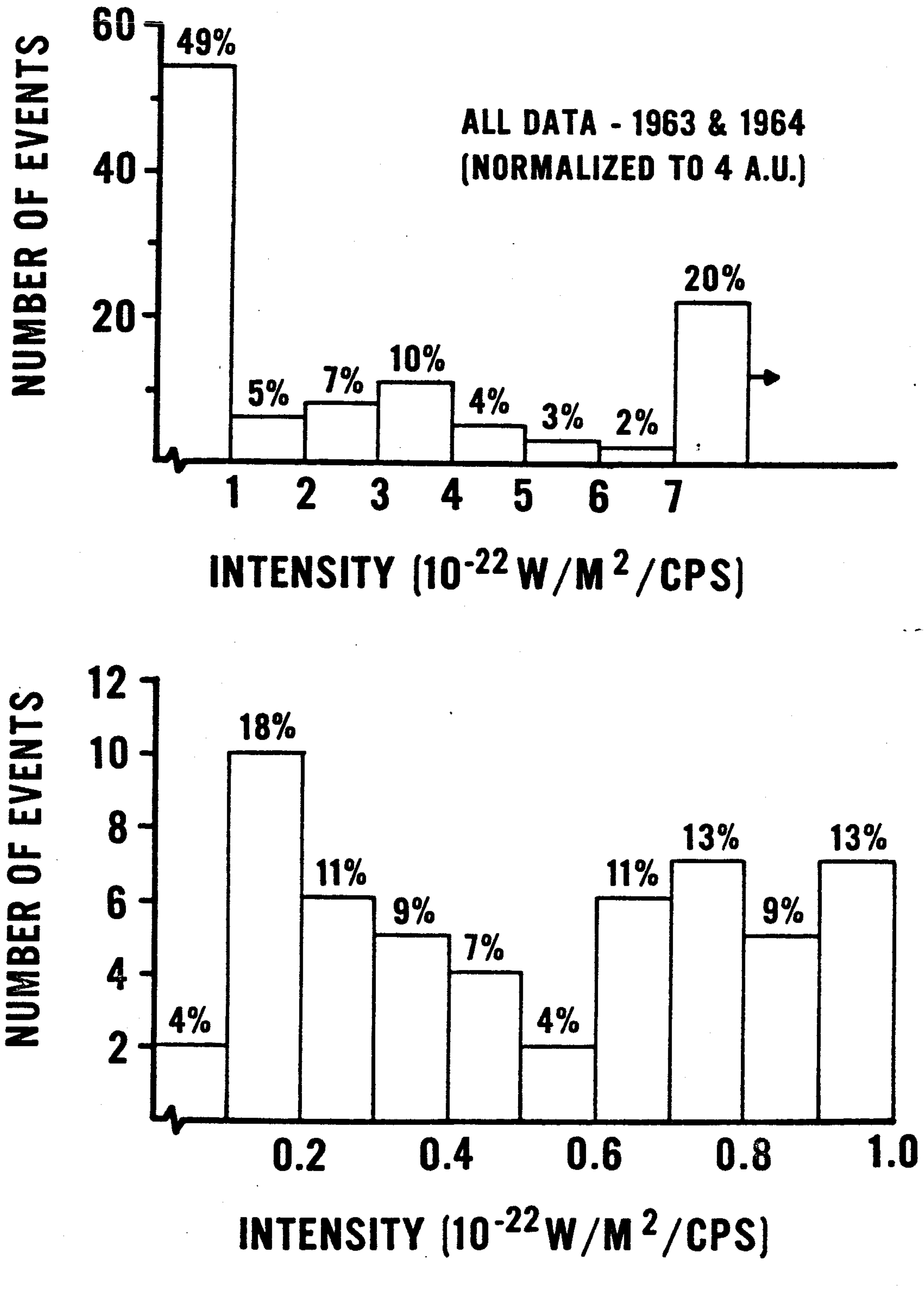

NUMBER OF EVENTS
30
20
10
66%
9%
9%
2%
2%
4%
14%
1964 DATA
(CONJUNCTION)
1
2
3
4
5
6
7
INTENSITY (10-22 W/M2/CPS)
NUMBER OF EVENTS
6
4
2
4%
19%
15%
19%
12%
4%
4%
12%
12%
0.2
0.4
0.6
0.8
1.0
INTENSITY (10-22 W/M2/CPS)

Figure 5.



60
40
20
NUMBER OF EVENTS
49%
5%
7%
10%
4%
3%
2%
20%
ALL DATA - 1963 & 1964
(NORMALIZED TO 4 A.U.)
1 2 3 4 5 6 7
INTENSITY (10-22 W/M2/CPS)
12
10
8
6
4
2
NUMBER OF EVENTS
4%
18%
11%
9%
7%
4%
11%
13%
9%
13%
0.2 0.4 0.6 0.8 1.0
INTENSITY (10-22 W/M2/CPS)

Figure 6.

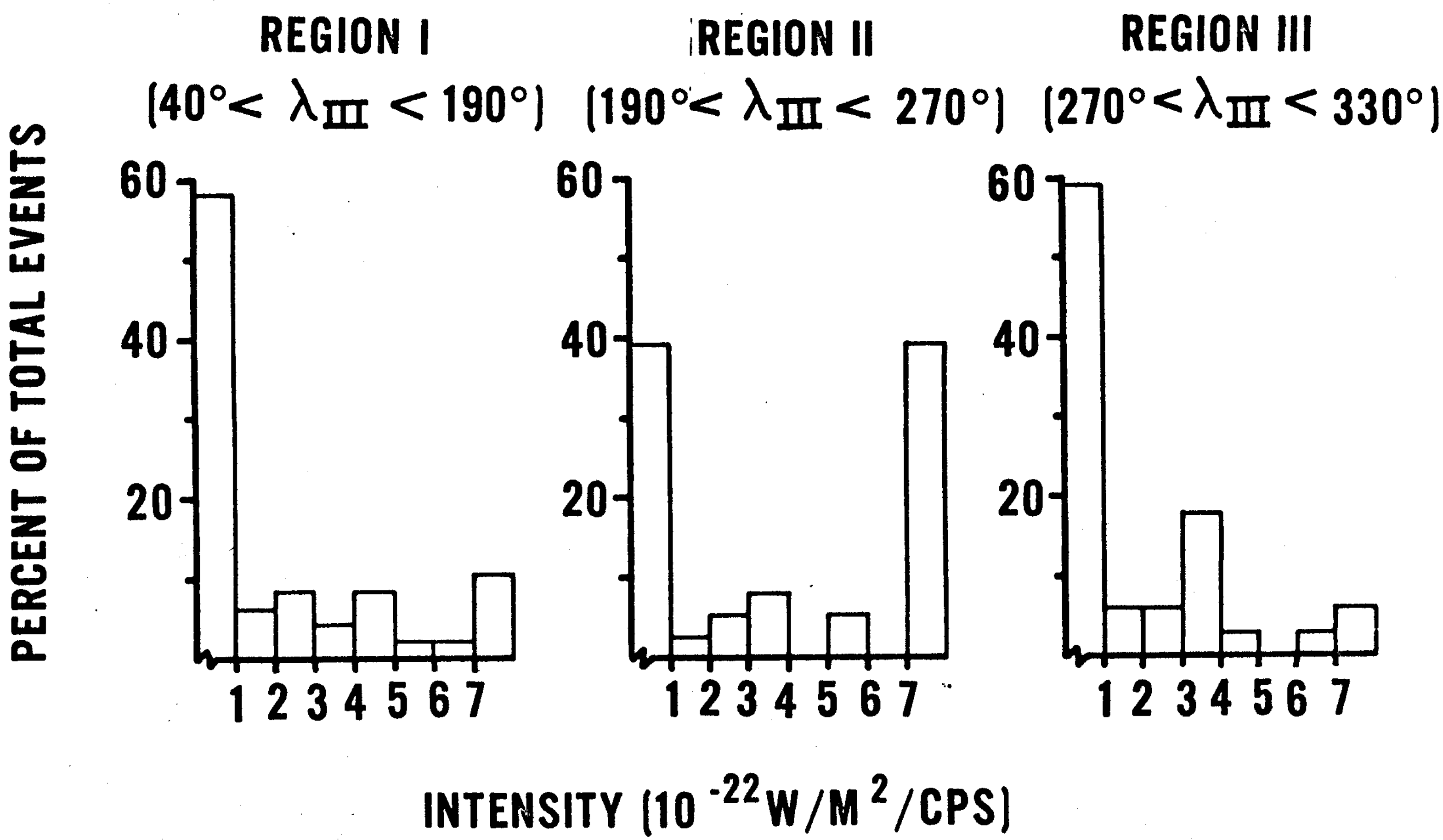

REGION I
(40°< λIII < 190°)
REGION II
(190°< λIII < 270°)
REGION III
(270°< λIII < 330°)
PERCENT OF TOTAL EVENTS
60
40
20
1 2 3 4 5 6 7
INTENSITY (10 -22W/M 2/CPS)

Figure 7.