Satellite and Rocket Observations in the Auroral Zone*

BERNT N. MAEHLUM

Department of Space Science
RICE UNIVERSITY
Houston, Texas

[redacted]

Invited Survey paper ~~to be~~ presented at the Birkeland Symp~~osium~~, Sept~~ember~~ 1967, (Sandefjord, Norway).

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INTRODUCTION

Recent studies in the auroral zone performed by rocket and satellite borne instruments can be separated into two groups, which refer to different regimes of temporal and spatial resolution. The first group includes studies of large scale phenomena in the auroral zone and statistical studies of various auroral phenomena. These, "climatological" studies of auroras, have mainly been based on satellite observations. The second group refers to studies of fine-structure within auroral forms, mainly based on rocket observations, which give us "snapshots" of the auroral "weather" at one particular place in a very limited time interval.

At present we have a certain amount of information on the auroral particle "climate" from a series of satellite observations, at least for electrons with energies greater than 10 keV in the altitude range 250-2000 km. In addition, scattered observations from sounding rockets have been obtained at high latitudes above various American and European rocket launch sites near the auroral zone, but very little has yet been done in a systematical way to study how the particle energy spectrum and pitch angle distributions vary near auroral forms.

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In the present paper a brief survey of the particle "climate" in the auroral zone will be given in Section 2 as a background for a more detailed discussion on peculiarities in the auroral zone during individual days, which will be presented in Sections 3, 4 and 5. Section 3 contains results from a recent study of the "quiet night" flux of auroral electrons, and individual observations of the auroral particle energy spectra and pitchangle distributions are discussed in Sections 4 and 5, respectively.

2. Average particle fluxes in the auroral zone.

In the present section we discuss only a few, average properties of the particle precipitation in the auroral zone. A more complete discussion of the particle "climate" has been presented by Brown (1966) and Hultqvist (1964).

The main qualitative results from statistical studies of precipitated electrons in the auroral zone are:

1) The precipitating fluxes of 10-100 keV energy electrons are generally higher and show more rapid time and spatial variations near the auroral zone than at other latitudes.

2) The average auroral electron energy spectrum appears to be more rich in low energy electrons (E<10 keV) than the electron spectra further south (O'Brien et al, 1964, McIlwain, 1960).

3) The fluxes of precipitated electrons above 40 keV show a significant increase with increasing geomagnetic activity. (O'Brien, 1964).

4) The pitchangle distribution of the auroral electrons varies with the electron fluxes. During time (or space) intervals of high fluxes in the auroral zone the distribution approaches isotropy. According to present belief the precipitated electron fluxes cannot exceed the trapped fluxes. I.e. an isotropic electron flux is the limiting pitchangle distribution during periods of enhanced precipitation.

5) The total energy carried by the precipitated electrons in the auroral regions has been estimated by O'Brien (1964) to vary between 4.10^{17} and 10^{18} ergs/sec during various degree of geomagnetic activity.

The rapid variations in the electrons fluxes in the auroral zone is thought to be the counterpart of the variations in the auroral brightness. Rocket observations show that the highest fluxes are generally found near the most luminous regions (McIlwain 1960, Davis et al, 1960; Ulwick, 1967), but unfortunately, very few observations are today available to actually show how the electron fluxes vary close to and inside auroral forms.

The first, and possibly still the only published simultaneous observations of precipitated electron fluxes and optical auroral intensity from a satellite was obtained by Injun 3 (O'Brien and Taylor, 1964). Figure 1,which has appeared in a number of recent review papers on auroras and particles shows an example of an excellent agreement between the location of a broad region of light emission and of high precipitation of electrons above 40 keV. The fine-scale structure in the electron energy and pitchangle distribution near the auroral forms was not discussed by O'Brien and Taylor (1964). For such studies one would probably need satellite borne

TV cameras and particle counters with extremely high time resolution.

Some effort has been put into the study of the high latitude trapping boundary and its relation to the auroral zone. The latitude changes in the position of the boundary of trapping is similar to the changes in the location of the auroral oval (Akasofu, 1967), and it has been suggested that auroral phenomena are closely related to this boundary (Maehlum and O'Brien, 1963), but it is not at all clear whether most of the various upper atmosphere phenomena in the auroral zone occur north or south of the boundary (Stolov, 1966; Lassen, 1967). Satellite observations have shown that very localized, low energy electron precipitation occurs outside of what is believed to be the "trapping boundary" (Fritz and Gurnett, 1965; McDiarmid et al, 1965), but the importance of these electrons in producing various upper atmosphere phenomena has, to my knowledge, never been investigated. Recently, Reid and Parthasarathy (1966) found excellent correlation between the electron fluxes at a distance of 28 earth radii in the geomagnetic tail and phenomena in the auroral zone. This observation indicates that at least some of the auroral phenomena are produced outside the region of electron trapping.

Very little is yet known about the proton fluxes in the auroral zone. It appeared early that the proton fluxes vary much more smoothly in time and space than the auroral electron fluxes (Davis et al, 1960). This is in good agreement with optical ground observations (See Eather, 1967). It is not yet certain whether the electron and proton fluxes are correllated, uncorrellated, or anticorrellated [Mozer and Briston, 1966; Romick and Elvey, 1958). The average ratio between the total precipitated electron energy and the precipitated proton energy has been measured by the Lockheed-group to be 5-10 (Evans et al, 1966). Albert (1967) has found that the total number of precipitated electrons in a visible aurora is about 100 times higher than the number of protons. A few rocket observations of precipitating proton fluxes show that the pitchangle distribution of the protons is isotropic or peaked in a direction normal to the local geomagnetic field (Sharp et al, 1966; Mozer and Bruston, 1966; Whalen et al, 1967).

Some 13 proton energy spectra have been obtained in the auroral zone by rockets. The best fit exponential spectrum has an e-folding energy of ~ 15 keV in the 1-100 keV energy range (Sharp et al, 1966; Albert, 1967 and Whalen et al, 1967) increasing to 50-150 keV for electron energies above 100 keV (Mozer, 1965, McIlwain, 1960; Mozer and Bruston, 1966; Søraas and Trumpy, 1966). The proton fluxes vary over many decades and the highest fluxes reported are $\sim 10^{8}$ sec^{-1} sterad^{-1} cm^{-2} (Albert, 1967; Whalen et al, 1967).

ELECTRON PRECIPITATION DURING GEOMAGNETICALLY CALM NIGHTS.

Most studies of electron precipitation in the auroral zone are based on data obtained during spectacular events, or data obtained during various degree of geomagnetic activity have been merged to give average values. Very little attention has been paid to the morphology of the "background electron drizzle" during quiet periods. The average, peak directional fluxes of precipitated electrons of higher than 40 keV energy vary between 10^{2} and 10^{5} #/cm^{2} sec sterad during periods of low geomagnetic activity at high latitudes (O'Brien, 1964), with a median value of 3.10^{3} #/cm^{2} sec sterad.

In order to study the quiet day electron precipitation in the auroral zone in some detail, data obtained by three Geiger counters on Injun 3 during a geomagnetically quiet period in Feb. 1963 were analyzed.

The three 6213 Geiger counters were mounted on the satellite in the directions 0^{o}, 50^{o} and 90^{o} relative to the local geomagnetic field vector and the satellite orientation was kept constant relative to the field by a bar magnet. Data from 50 satellite passes, which were distributed uniformily throughout local night (between 2130 and 0700) were used in the analysis.

The first result from this study to be discussed is related to the diurnal variation in the electron precipitation during quiet nights. During all pre-midnight passes there was an extremely well defined northern boundary (L_N) in the fluxes of trapped electrons (Figure 2). Just south of this boundary there was a narrow region of electron precipitation, and the particles showed a high degree of isotropy in this region. Further south the fluxes of electrons were always highly anisotropic, although electron precipitation occasionally occurred at some distance from the boundary.

After midnight, and in particular toward the morning hours the electron fluxes were more isotropically distributed over a large latitude interval, and the fluxes of precipitated electrons were generally highest in the morning. During none of the post-midnight passes did we observe a sharp northern terminal in the trapped electron fluxes similar to what was found before midnight. The transition from a narrow to a broad region of precipitation seems to occur close to local midnight.

One could speculate whether this evening-morning assymmetry in the electron precipitation during quiet conditions indicates that the region of accelleration actually is broader in the late night than in the evening hours, or if the assymmetry is caused by a non-symmetrial geomagnetic "guiding" between the accellerating region and the auroral zone. No similar assymmetries have been reported in the equatorial electron fluxes, but recent observations by Freeman and Maguire (1967) show that at least protons are affected by some non-symmetrical processes in the equatorial plane or in the geomagnetic tail.

Most of the earlier statistical studies of high latitude electron precipitation have been referred to a frame of reference which is fixed relative to the earth, and this may be the reason why the peculiarities in the diurnal variations during quiet conditions have not been seen before. In order to do a proper statistical study of particle precipitation, in particular before local midnight, one should probably use a frame of reference which is fixed relative to the boundary of trapping. The boundary of trapping seems to be a natural origin for studies of high latitude phenomena, just as the auroral oval would provide a convenient reference for optical phenomena (Akasofu, 1967). In Figure 3 data from 10 pre-midnight passes are plotted in an L-coordinate system with the high latitude boundary as origin. The narrow region of isotropic pitch angle distribution south of L_N is clearly seen in this plot.

The time and spatial variations in the electron energy spectrum could not be studied during the geomagnetically quiet period, because the electron fluxes were too low. The photometric observations (λ = 3914Å) did, however, indicate that the low energy electron fluxes normally showed a peak near L_N, although there were some exceptions. (Figure 4). During revolution 807 the spatial distribution of the light differed significantly from the pattern of the "high" energy electron precipitation.

Earlier observations by Williams (1966) have shown that the boundary of trapped electrons is different for different energies.

We do not know whether the peak in the visual aurora north of L_N shown in Figure 4 (Rev. 807) actually is inside a low energy electron trapping region, or if precipitation of low energy electrons occasionally takes place north of the boundary of trapping (McDiarmid and Burrows, 1965; Fritz and Gurnett, 1965) even during geomagnetically quiet conditions.

Very little data from optical measurements on the satellite are available for the period after local midnight, and we are not in a position to investigate how the "width" of the optical auroral zone varies during the night during quiet conditions. Recent works by Feldstein and Starkov, (1967) have, however, shown that a midnight expansion in the "zone of light" can be traced from all-sky camera observations. They find that the average "zone of light" increases from $\sim 2^{o}$ to $\sim 5^{o}$ near local midnight during geomagnetically quiet periods, in fair agreement with our findings.

Electron energy spectra in auroras

Recent years' extensive studies of the precipitated electron fluxes have shown that the auroral electrons generally have a much softer energy spectrum than the electrons in the hearth of the outer radiation zone (O'Brien et al, 1962; Sharp et al, 1965). Most of the differential electron energy spectra have been approximated by a power law spectrum with exponent γ = 4-6, or by an exponential spectrum with e-folding energy E_o = 5-25 keV in the 10-100 keV energy region (McIlwain, 1960; Sharp et al, 1965; O'Brien et al, 1962) upon which there occasionally is superposed a "linespectrum" (McIlwain, 1960; Johnson et al, 1967).

A systematic change in the shape of the electron energy spectrum with geomagnetic activity or with auroral luminosity has never been reported, although it has been suggested that there are two distinct types of spectra caused by different sources (Evans, 1967). The first spectrum; which is observed near luminous regions is steep; whereas the other type of spectrum, which is much flatter, is observed in conjunction with auroral radio wave absorption (Brown, 1966; McDiarmid and Budzinski, 1964; Evans, 1967). Recent detailed rocket observations of the electron energy spectrum obtained inside and near auroral forms show that there is no general "softening" in the spectrum with increasing luminosity. In fact, the softest spectrum seems to be observed in auroral glow (McIlwain, 1960) whereas the average electron energy is much higher inside auroral forms (Ulwick, 1967).

A series of recent electron observations in the auroral zone have shown that the extent of electron precipitation near visual aurora vary with the energy, and there are some indication that the highest luminosity regions coincide with "hard" regions of the electron spectrum, and the luminous regions are surrounded by "softer" electron spectra (Evans, 1967).

O'Brien and collaborators (LaQuey et al, (1965) and Westerlund et al, (1965)) measured the electron spectrum in the 4-10 keV region in and near an auroral band by a sounding rocket in 1963. They found that inside the auroral band the differential electron spectrum was almost "flat" in the 4-10 keV region. Near the boundary of the band there was a significant softening in the electron spectrum as the lowest energy electron precipitation extended over a significantly larger region in space (or time) than the higher energy electrons. In fact, the low energy electron fluxes reached a maximum value near the boundary of the band. No electron flux variations were observed above 50 keV.

Similar indications of spectral hardening inside auroral forms have been observed by Evans (1967) and Riedler (1966), although the hardening in these cases extends to much higher energies than what was observed during the experiment reported by Westerlund et al, (1965). Evans' observation was obtained close to local midnight in the vicinity of an auroral band. Although the auroral luminosity near the rocket showed significant variations during the flight, the low energy ($E_e \lesssim 4$ keV) electron fluxes stayed almost constant. The high energy electron fluxes ($E_e > 40$ keV) on the other hand, "followed the observed variations in the intensity of the zenith auroral form" (Evans, 1967). Sharp et al, (1965) conclude on the basis of satellite observations that the largest variations in the electron fluxes near auroral forms occur in the energy range above 10 keV, which indirectly supports Evans' findings.

The most striking example of the spectral hardening in the electron energy range below 100 keV near visual auroral forms has been presented by Riedler (1966), who conducted a 5 energy channel electron spectrometer rocket experiment which was launched into quiet auroral forms after local midnight. The rocket also carried a photometer with a 4278Å filter (courtesy A. Omholt) which provides an excellent tool for locating the position of the auroral forms. The time variations of the photometer output and the variations in the electron fluxes ($E > 40$ keV) are shown in Figure 5. The maxima in the light intensity occurred close to the maxima in the electron fluxes.

A full discussion of the time variations in the spectrum has been given by Riedler (1966). In this paper we will concentrate on a qualitative discussion, based on the ratio between the integral fluxes of electrons above 40 keV and 64 keV, respectively. There is a clear, negative correlation between this ratio and the electron fluxes (see Figure 5), and the highest values of this ratio were observed close to the peaks in the auroral luminosity. Similar variations are found if the integral fluxes of electrons above 40 keV energy are compared with the other energy channels on the rocket below 100 keV. The spectra found by Riedler do not conform to any of the "standard"(exponential or power law) spectra .It is interesting to note, however, that the ratios between the electron fluxes above 40 and 64 keV correspond to very hard equivalent power law spectra. Near the peaks the equivalent power law spectra can be characterized by an exponent $\gamma = 2$, which is much less than what is normally found at these latitudes (O'Brien et al, 1962).

The variations in the average differential energy spectrum near $t = 170$ sec as deduced from Riedler's integral spectral observations are given in Figure 6, which clearly demonstrates how the relative abundance of high energy electrons increase toward the peak ($t = 175$ sec). In fact, near $t = 175$ sec there is probably a maximum in the spectrum close to $E = 90$ keV, as shown by Riedler (1966).

From these observations we conclude that although the relative abundance of low energy electrons is very high in the auroral zone when averaged over several kilometers (as done by satellite borne counters), the spectrum inside the visual forms seems to be populated by a relatively higher number of electrons above 10 keV energy than the "background" spectrum. This means that the satellite data should be used with caution, if one wants to investigate the auroral forms and their origin.

Pitch-angle distributions of auroral particles

A large number of particle pitchangle distribution studies have been reported in literature during recent years. The particle pitchangle distribution is believed to provide information on (a) the location of the source of accelleration (Hultqvist, 1964; Anger, 1967), (b) low altitude geomagnetic field distortions and electric fields (McDiarmid et al, 1961 ; Cummings et al, 1966; Mozer and

Bruston, 1966; Evans, 1966) and (c) the importance of atmospheric scattering (O'Brien, 1964; Maehlum and Stadsnes, 1967 and Walt et al, 1967).

Except for a very limited number of "irregular" pitchangle distributions of precipitated particles, which will be discussed in the following, the observations can be grouped into two classes: (i) During periods of low precipitation the fluxes are peaked in a direction normal to the geomagnetic field lines. This has been interpreted as an indication that the "loss cone" has been developed through multiple particle bounces between the hemispheres. (ii) During periods of high particle precipitation the fluxes appear to be isotropically distributed over the upper hemisphere. Satellite borne counters have never seen pitchangle distributions of particles which are peaked in a direction along the geomagnetic field lines. This has been interpreted as an indication that the particle accelleration takes place in a region of space where the geomagnetic field is much lower than the field in the auroral zone (Hultqvist, 1964; Anger, 1967).

Satellite borne counters have also been used for studies of the electron "albedo". It has been found that the average number of "downgoing" electrons in the energy regions 15 eV-10 keV and 40 keV-200 keV is about ten times higher than the average number of "upgoing" electrons in the same energy intervals (O'Brien, 1964; Johnson et al, 1967; McDiarmid et al, 1966). These numbers are in fair agreement with theoretical estimates if the precipitated electrons are assumed to be isotropically distributed (Stadsnes and Maehlum, 1965; Walt et al, 1967). Most rocket observations of pitchangle distributions of precipitated and back-scattered electrons and protons support the general picture obtained from the satellite data, although the pitchangle coverage of the particle observations from rockets generally is very incomplete. Three peculiar pitchangle distributions which deviate significantly from the rest have been presented by McDiarmid et al, (1961); Cummings et al, (1966); and Mozer and Bruston, (1966). All of these distributions show a significantly higher relative particle flux up the field lines than what could apparently be accounted for by simple coulomb scattering. No similar abnormal electron albedo fluxes have ever been observed at satellite altitudes.

This introduces the question of possible electron pitchangle distortions between satellite altitudes and altitudes where various auroral phenomena occur, due to low altitude electric fields and/or geomagnetic field distortions. The presence of a field-aligned electric field will (a) shift the mirror points of the precipitated particles up and down in the atmosphere, which cause changes in the electron scattering and (b) accelerate charged particles of thermal energies in the electric field region. Such mechanisms have been suggested by McDiarmid et al, (1961) and Mozer and Bruston, (1966) to explain certain abnormal pitchangle distributions observed. Although field-aligned electric fields have been observed (Mozer and Bruston, 1967), it is not clear how important these fields are in modulating the particle fluxes at low altitudes.

Another pitchangle modulating effect suggested by Cummings et al, (1966) refers to the geomagnetic field distortion caused by the auroral current system. Recent, quantitative studies of the interaction between the pitchangle distribution of precipitating electrons and the auroral current show that this effect can cause a significant distortion in the particle pitchangle distribution between rocket and satellite altitudes (Maehlum and O'Brien, 1967). This effect is of particular importance when the fluxes of electrons are anisotropic. In a region of enhanced geomagnetic field the electron albedo is much higher than normal, partly because of a general "lifting" of the mirror points above the atmosphere, partly because electrons which enter the atmosphere at high pitchangles are easily scattered out of the atmosphere (Maehlum and Stadsnes, 1967). In the regions where the auroral current system causes decreases in the geomagnetic field there will correspondingly be a decrease in the albedo, due to enhanced scattering and absorption in the atmosphere.

For a current system which causes a disturbance on the ground of a few hundred gammas, the field close to the current at 100-160 km altitude may actually deviate from the quiet day value as much as 10-15 percent if the current has a filamentary structure. It is interesting to note that an increase of 15 percent in the geomagnetic field between 100 and 160 km would cause most of the precipitated protons observed by Mozer and Bruston (1966) to mirror above the atmospheric scatter region (Figure 7), which means that the fluxes of downgoing particles should equal the fluxes of upgoing particles. This is actually what was observed at that particular period, from which Mozer and Bruston (1966) "in lack of other possibilities" concluded that a strong electric field parallel to the geomagnetic field lines was present below 300 km. Without knowing possible effects on other proton energies and on other types of charged particles one can hardly distinguish between electric and geomagnetic sources for pitchangle modulations.

The abnormal high electron albedo observed by Cummings et al, (1966) has never been explained, although a detailed analysis of the problem has been done by the authors and others (Walt et al, 1967).

Unfortunately, in almost no cases have the complete pitchangle distributions of precipitated particles been measured, and it is therefore difficult to evaluate how much simple coulomb scattering actually contributes to the apparent particle albedo. In order to illustrate the problem let us consider three model pitchangle distributions for precipitating electrons and compute the pitchangle distribution of backscattered electrons [Figure 8]. The precipitated electron spectrum is assumed to obey an exponential law with e-folding energy E_o = 25 keV, and the fluxes are assumed to be measured by an integral particle counter with low-energy cut-off at E_c = 40 keV.

When the precipitated electrons have an isotropic pitchangle distribution, (Figure 8A), the ratio ($R(\alpha)$) between the electron fluxes in the lower and the upper hemisphere varies between 1.0 and 0.1. This is in agreement with satellite observations (O'Brien, 1964).

For field-aligned electron fluxes (Figure 8B) $R(\alpha)$ is significantly higher than unity in directions normal to the local geomagnetic field line. It was suggested by Stadsnes and Maehlum, (1965) that this electron configuration could explain the abnormal electron albedo observed by McDiarmid et al. (1961). However, as field-aligned electron fluxes have never been observed from satellites, this explanation does not appear too attractive (Walt et al, 1967).

When the electron fluxes are peaked in a direction normal to the geomagnetic field vector (Figure 8C) the over-all fluxes of albedo electrons are fairly high, and for low pitchangles $R(\alpha)$ exceeds unity. It is interesting to compare this illustration with the abnormally high electron albedo observed by Cummings et al, (1966). Near the beginning of the flight the observed reflection coefficient was equal to unity, and the pitchangle distribution was peaked in a direction normal to the local field. The angles between the rocket axis and the two electron detectors were $\alpha = 50^{\circ}$ and $\alpha = 130^{\circ}$, respectively. If the rocket axis happened to be oriented parallel to the local field vector, the counters would have been looking into the region where the apparent reflection coefficient ($\underline{R(\alpha)}$) is close to unity and this could possibly explain the abnormally high values observed. Figure 8 clearly demonstrates the importance of knowing the complete angular distribution of the particles when studies of low altitude pitchangle modulations are performed.

CONCLUDING REMARKS

Upper atmospheric phenomena in the auroral zone show rapid variations in time and space, and comparison between average values of various particle and upper atmosphere observations can give very misleading results.

Recent years' systematic satellite observations of precipitated particle fluxes have shown that the fluxes vary by many orders of magnitude at high latitudes, but very few attempts have yet been made to relate these variations to actual variations in the auroral luminosity, upper atmosphere ionization etc. Rocket observations have shown particle pitchangle and energy distributions which deviate significantly from the average values obtained from satellite observations. It is not yet clear whether the differences are caused by statistical spread in the data, or if various low-altitude processes may modulate the particle fluxes below satellite altitudes.

In order to study the relationship between the particle fluxes at satellite altitudes and auroral fine-structured phenomena in more detail, one needs high time resolution counters and TV cameras on the same satellite, such as O'Brien is planning in the OWL-satellites, or synoptic, well coordinated ground-based observations of auroral structure and satellite observations of particle precipitation, such as done by the Lockheed-group (Johnson, et al. 1967).

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FIGURE CAPTIONS

Figure 1. Simultaneous observations of trapped and precipitated electrons and optical emission from the atmosphere (O'Brien, 1964).

Figure 2. "Trapped" ($\alpha = 90^{\circ}$) and "precipitated" ($\alpha = 50^{\circ}$) fluxes of higher than 40 keV energy electrons at various local hours during quiet conditions in the auroral zone.

Figure 3. Latitudinal variations of the "indices of isotropy" (upper part) and the fluxes of precipitated electrons (lower part). All observations are referred to a coordinate system which is fixed relative to the high latitude boundary of trapping (L_N).

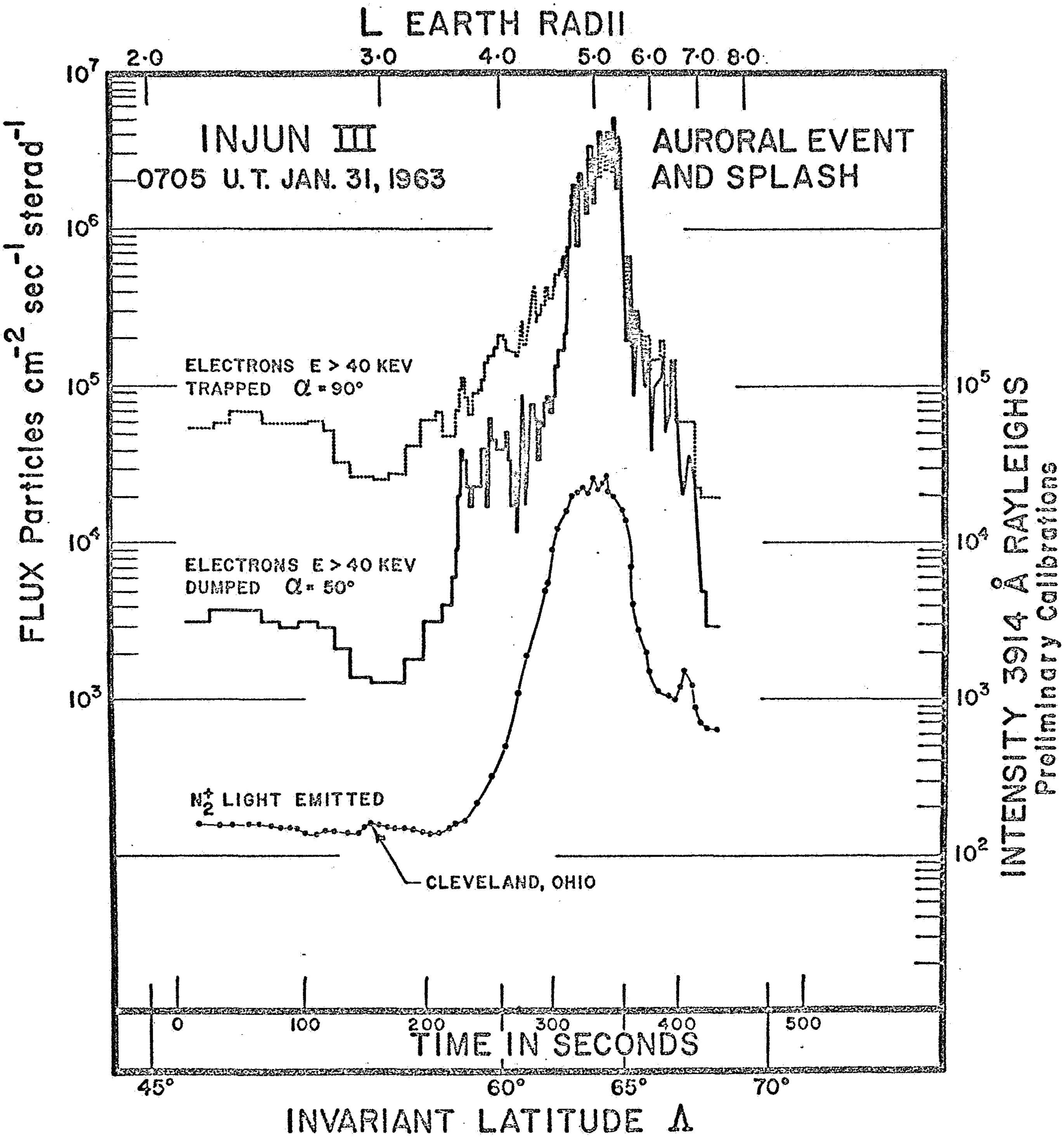
Figure 4. Latitudinal variations of the electron precipitation and the intensity of optical emission ($\lambda = 3914Å$) in the upper atmosphere during three satellite passes over North America.

Figure 5. Optical and particle observations obtained during an auroral event over Andenes, Norway (Courtesy Riedler, 1966).

Figure 6. Variations in the electron energy spectrum inside auroral structure (courtesy Riedler, 1966).

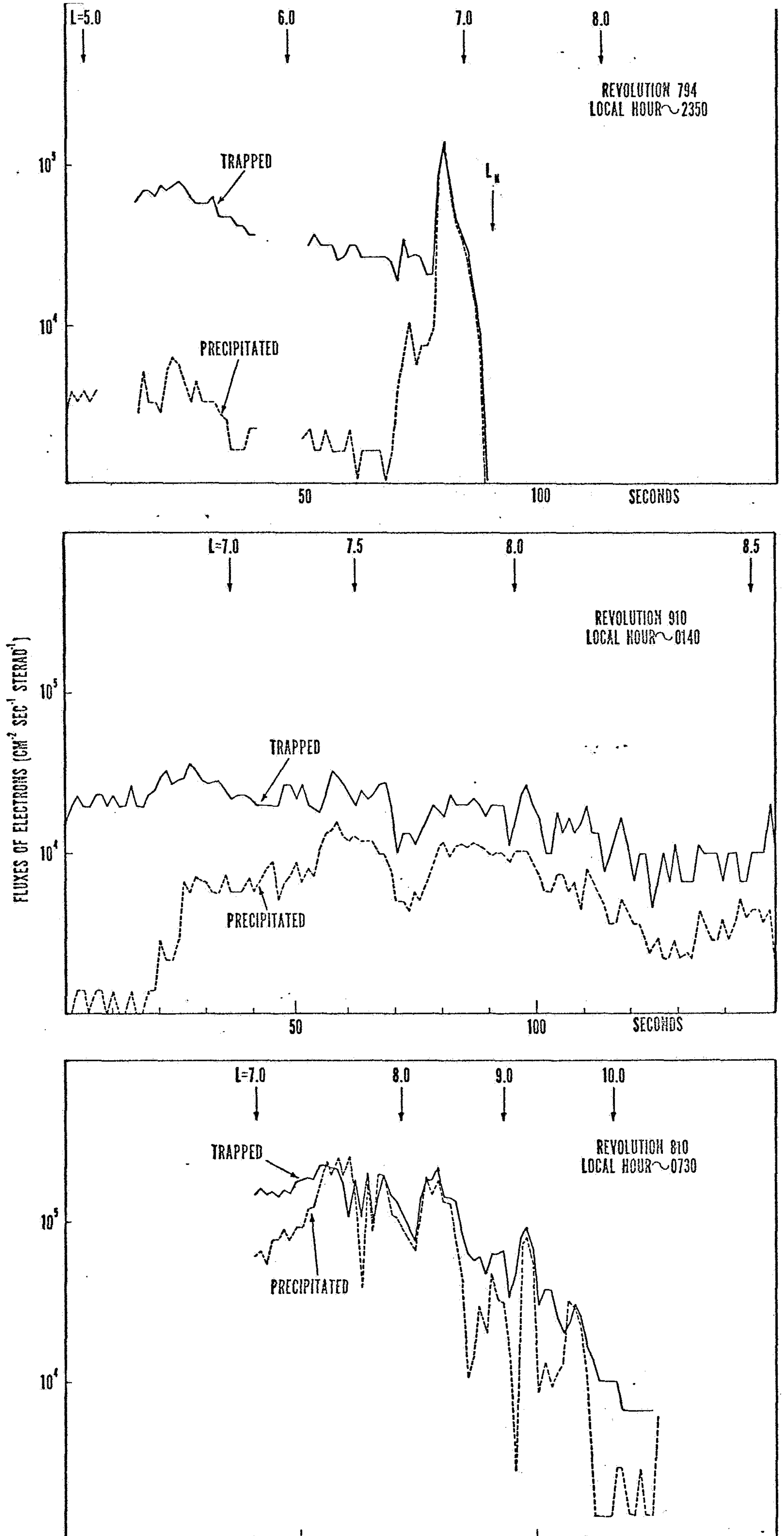
Figure 7. Pitch angle distribution of precipitated protons at an altitude of 300 km in the auroral zone (Courtesy Mozer and Bruston, 1966).

Figure 8. Backscattered fluxes of electrons (broken lines) computed for three model pitch angle distributions of precipitated electrons (full lines).



L EARTH RADII
2·0
3·0
4·0
5·0
6·0
7·0
8·0
10^7
10^6
10^5
10^4
10^3
FLUX Particles cm^-2 sec^-1 sterad^-1
INJUN III
0705 U.T. JAN. 31, 1963
AURORAL EVENT
AND SPLASH
ELECTRONS E > 40 KEV
TRAPPED α = 90°
ELECTRONS E > 40 KEV
DUMPED α = 50°
N2+ LIGHT EMITTED
CLEVELAND, OHIO
10^5
10^4
10^3
10^2
INTENSITY 3914 Å RAYLEIGHS
Preliminary Calibrations
0
100
200
300
400
500
TIME IN SECONDS
45°
60°
65°
70°
INVARIANT LATITUDE Λ

Figure 1


L=5.0
6.0
7.0
8.0
REVOLUTION 794
LOCAL HOUR~2350
TRAPPED
PRECIPITATED
L_K
10^5
10^4
50
100
SECONDS
L=7.0
7.5
8.0
8.5
REVOLUTION 910
LOCAL HOUR~0140
FLUXES OF ELECTRONS (CM^{-2} SEC^{-1} STERAD^{-1})
TRAPPED
PRECIPITATED
10^5
10^4
50
100
SECONDS
L=7.0
8.0
9.0
10.0
REVOLUTION 810
LOCAL HOUR~0730
TRAPPED
PRECIPITATED
10^5
10^4
50
100
SECONDS

2.

Figure 2

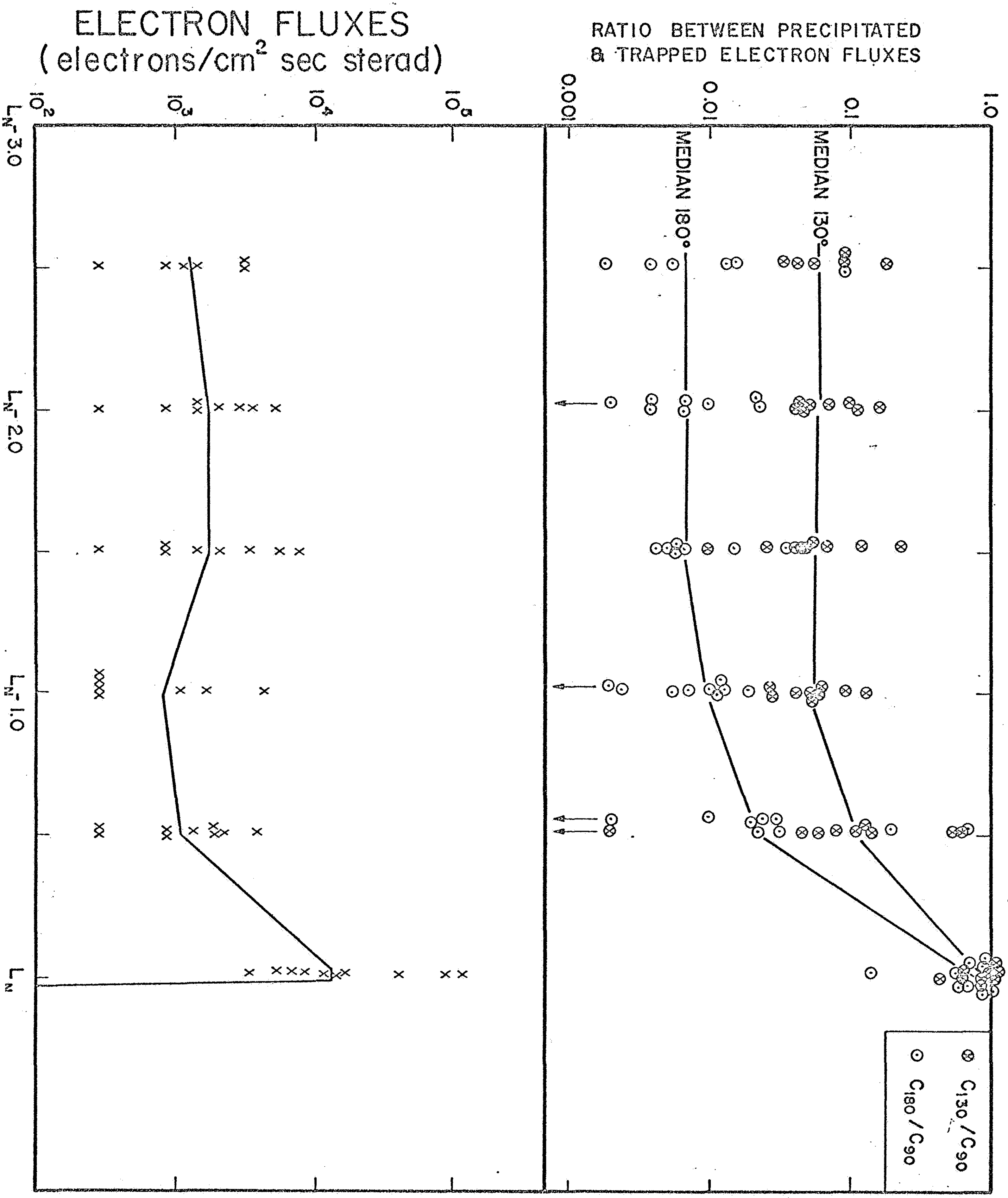
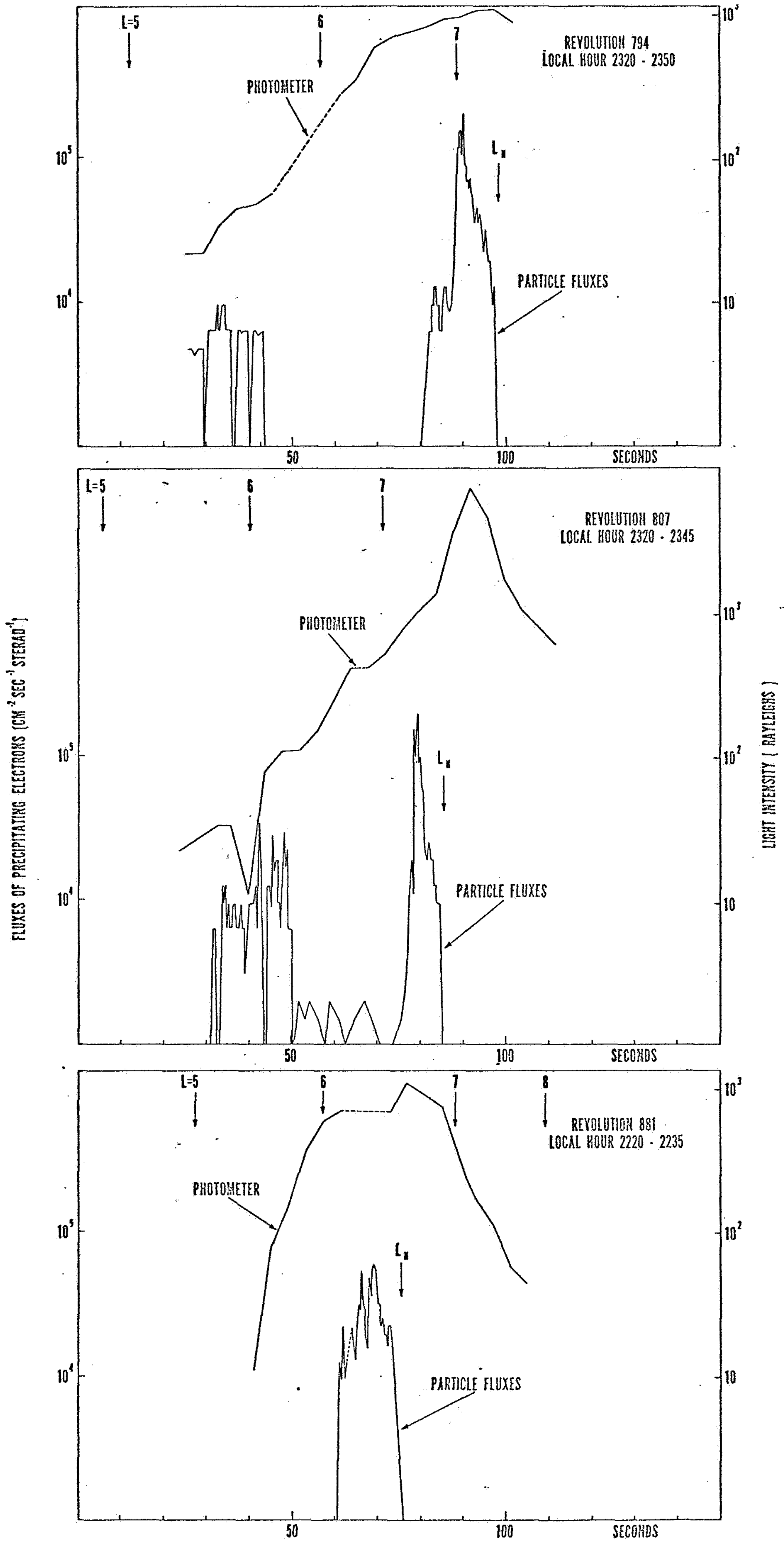

ELECTRON FLUXES
(electrons/cm^2 sec sterad)
10^2
10^3
10^4
10^5
RATIO BETWEEN PRECIPITATED
& TRAPPED ELECTRON FLUXES
0.001
0.01
0.1
1.0
MEDIAN 180°
MEDIAN 130°
L_N-3.0
L_N-2.0
L_N-1.0
L_N
C_{130}/C_{90}
C_{180}/C_{90}

Figure 3



L=5
6
7
REVOLUTION 794
LOCAL HOUR 2320 - 2350
PHOTOMETER
L_K
PARTICLE FLUXES
50
100
SECONDS
L=5
6
7
REVOLUTION 807
LOCAL HOUR 2320 - 2345
PHOTOMETER
L_K
PARTICLE FLUXES
50
100
SECONDS
L=5
6
7
8
REVOLUTION 881
LOCAL HOUR 2220 - 2235
PHOTOMETER
L_K
PARTICLE FLUXES
50
100
SECONDS
FLUXES OF PRECIPITATING ELECTRONS (CM^{-2} SEC^{-1} STERAD^{-1})
LIGHT INTENSITY (RAYLEIGHS)
10^5
10^4
10^3
10^2
10

Figure 4

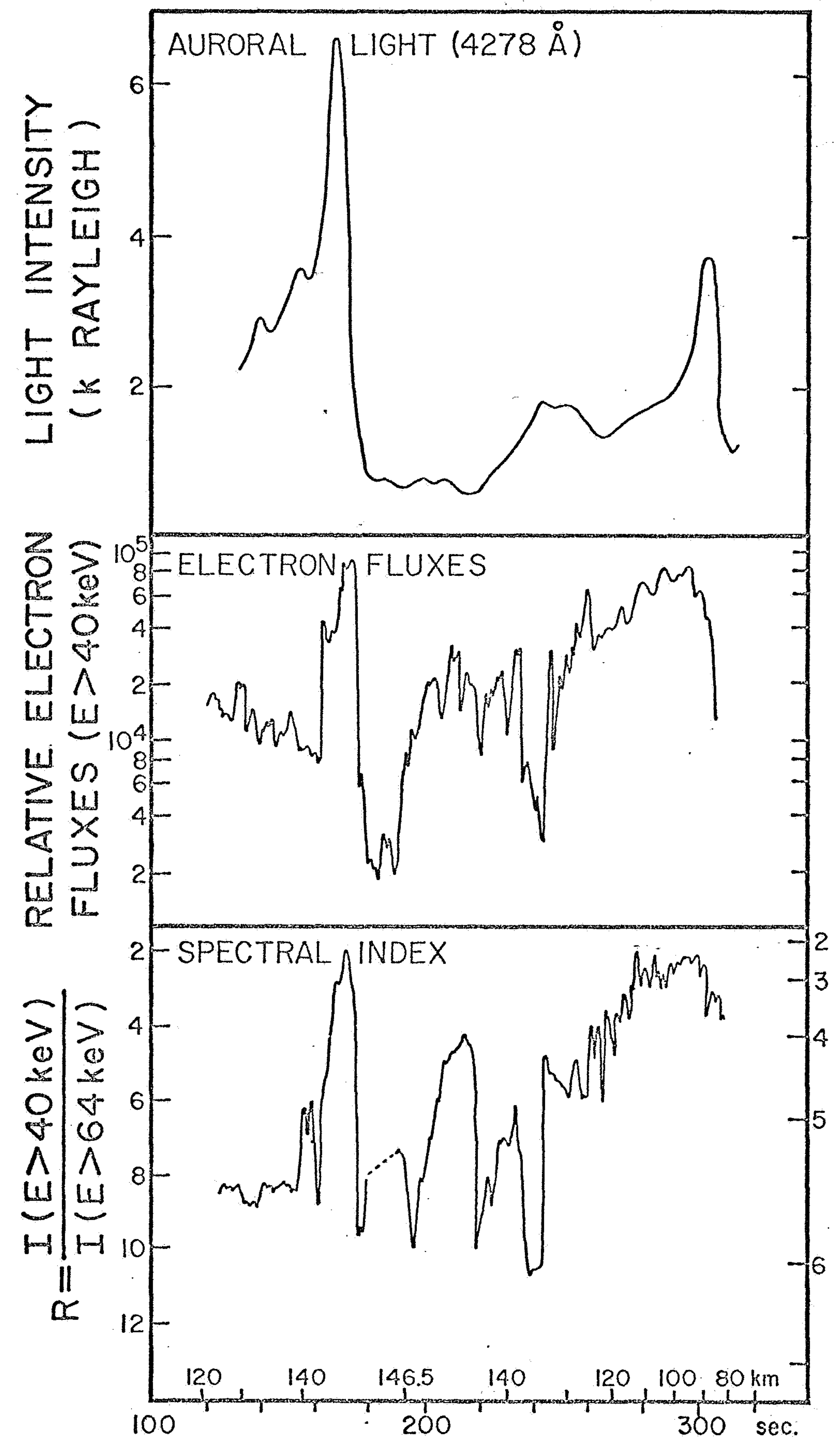


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Figure 5

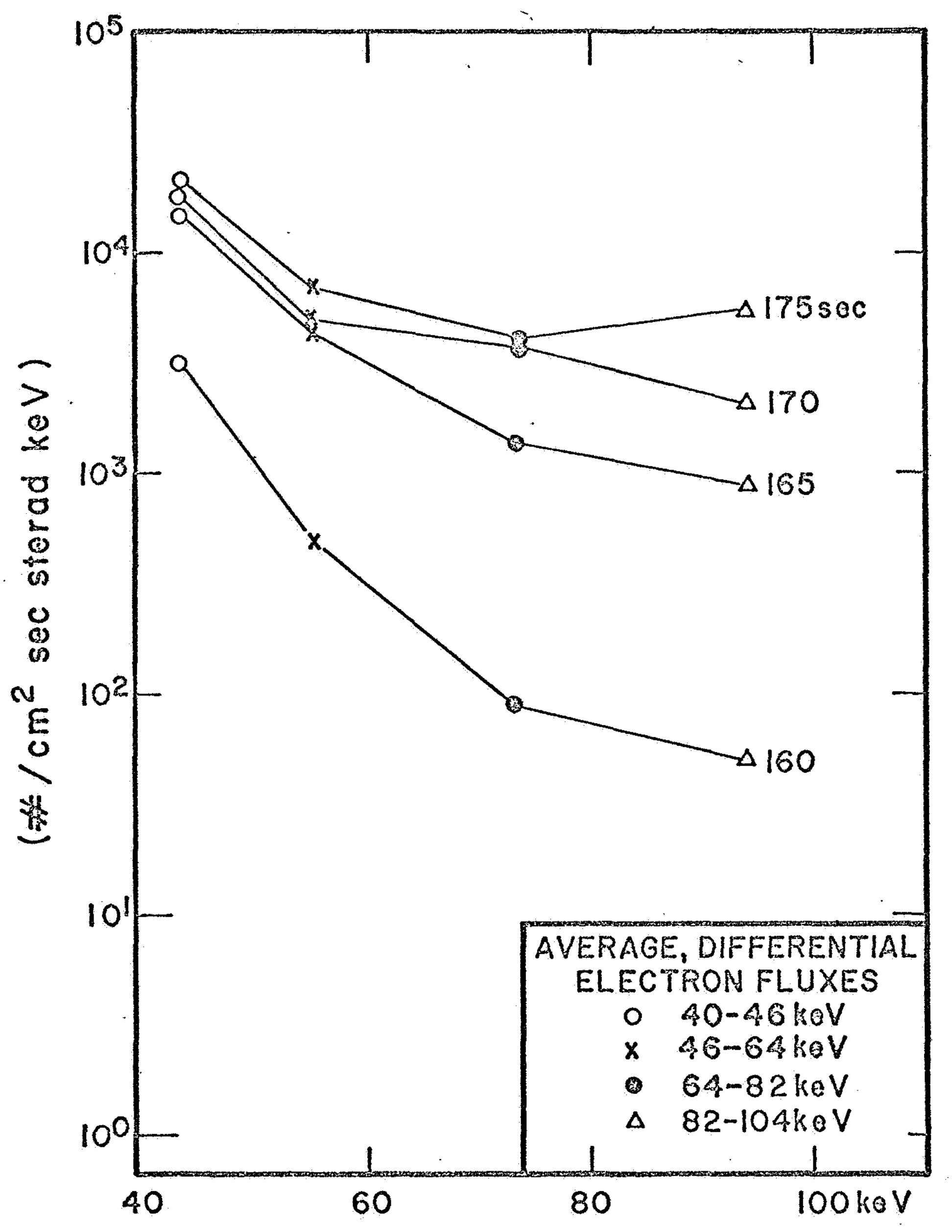
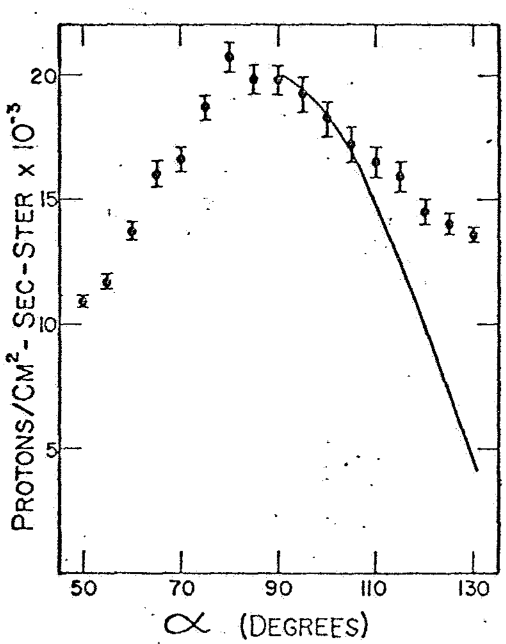


Figure 6

201312



PROTONS/CM^2 - SEC - STER x 10^{-3}
20
15
10
5
50
70
90
110
130
α (DEGREES)

Figure 7

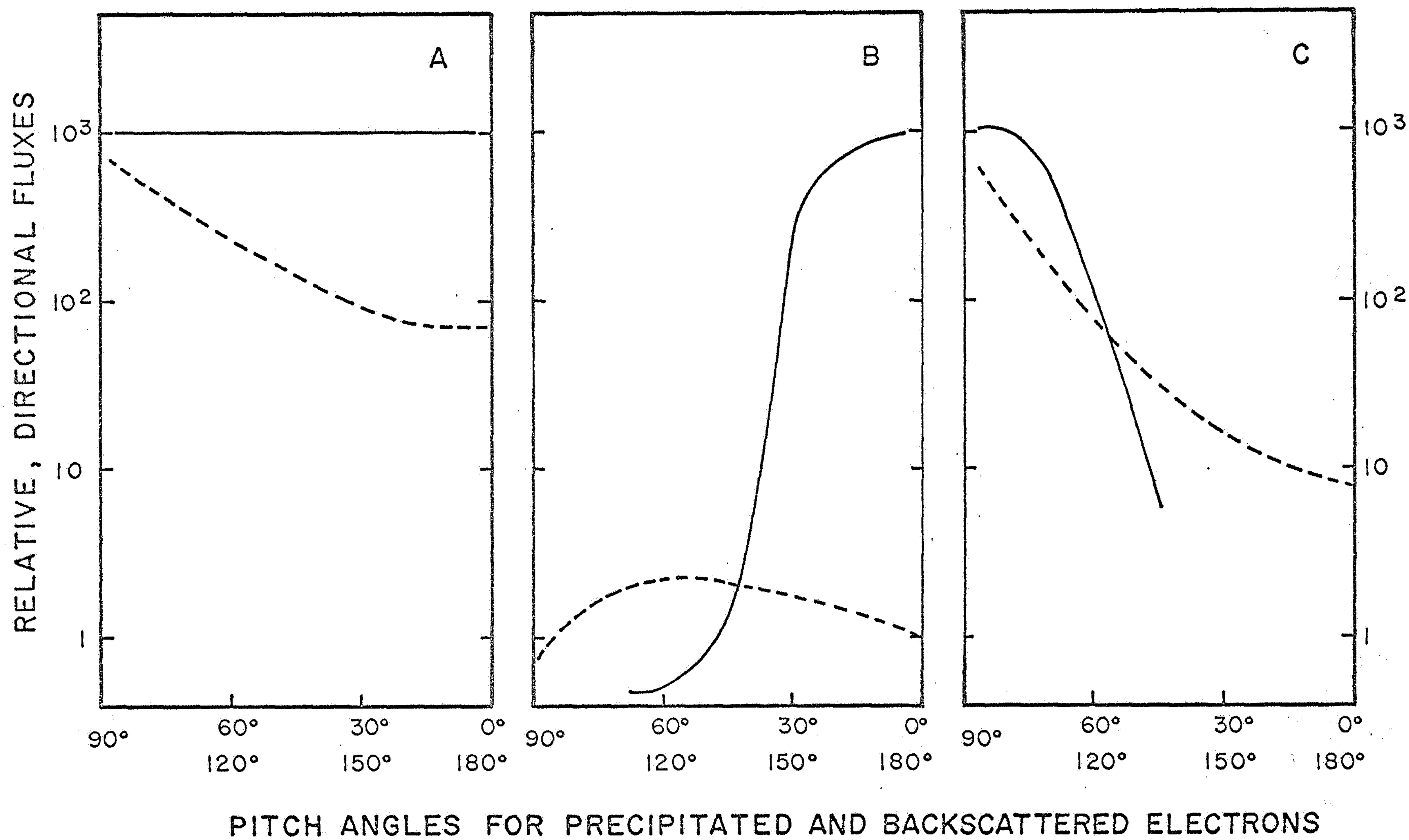


Figure 8

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