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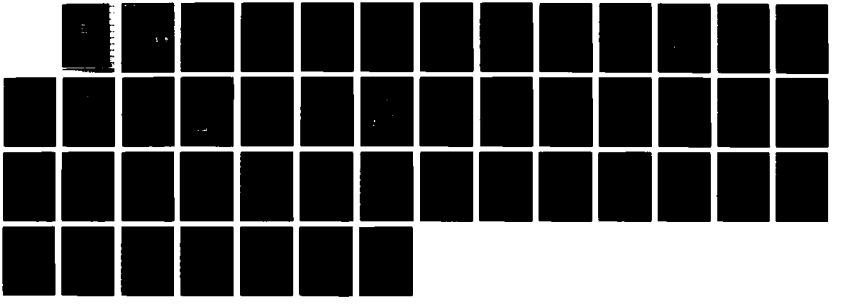

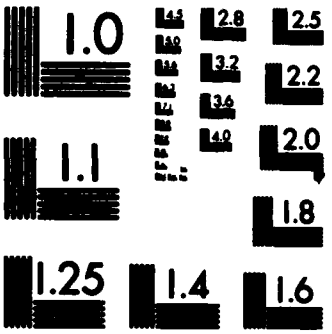


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# Analytic and Observational Approaches to Spacecraft Auroral Charging

T. G. Barker

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A Division of Maxwell Laboratories
P.O. Box 1620
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November 1986

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The objective of this report is to present a set of computational tools which can be used to process large quantities of observations of auroral electron and ion fluxes to yield estimates of the likelihood of spacecraft charging. The tools and procedures would be tested on the DMSP observations of environments and spacecraft charging, and then be used to predict the levels of charging for the shuttle in polar orbits. We have presented two approaches. The first approach, the subject of Section II, is to fit the observed spectra to analytic functions which can then be manipulated to find the charging potential. The analytic functions proposed by Fontheim, et al., (1985), to represent electron flux spectra, are parameterized by a set of observable physical parameters. The second approach, described in Section III, is to numerically integrate the observations directly. The second approach is more appropriate for large numbers of spectra, while the first provides physical parameters which give insight to the nature of the precipitating electron environment. The appendix of this report is a user's manual for the computer programs which (over)

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19. ABSTRACT (Continued)

CONT → perform these tasks. ←

## TABLE OF CONTENTS

# I. INTRODUCTION

The objective of this report is to present a set of computational tools which can be used to process large quantities of observations of auroral electron and ion fluxes to yield estimates of the likelihood of spacecraft charging. The tools and procedures would be tested on the DMSP observations of environments and spacecraft charging, and then be used to predict the levels of charging for the shuttle in polar orbits. We have presented two approaches. The first approach, the subject of Section II, is to fit the observed spectra to analytic functions which can then be manipulated to find the charging potential. The analytic functions proposed by Fontheim, *et al.*, (1985), to represent electron flux spectra, are parameterized by a set of observable physical parameters. The second approach, described in Section III, is to numerically integrate the observations directly. The second approach is more appropriate for large numbers of spectra, while the first provides physical parameters which give insight to the nature of the precipitating electron environment. The appendix of this report is a user's manual for the computer programs which perform these tasks.

## II. CHARGING CALCULATIONS USING THE FONTHEIM FORMULA

### 2.1 INTRODUCTION

In this section we provide a means for predicting satellite charging by expressing the electron flux in a formulation given by Fontheim, *et al.,* (1982) and then computing the net currents and charging voltages. In the following we outline the Fontheim formulation and show examples of applications for an expected range of parameters estimated by inspection of results published in several papers. The examples are displayed as a set of plots with contours which divide parameter space into charging and noncharging regions. Given a set of parameters which fit a data set, plots of this layer could be used as templates to predict charging.

### 2.2 THE FONTHEIM FORMULA

Fontheim, *et al.* (1982), combined the work of previous authors with their own statistical study of satellite observations of precipitating electrons to derive an expression for flux spectra. The expression is

$$\phi(E) = \phi_p + \phi_m + \phi_G, \tag{2.1}$$

where

$$\phi_p = \begin{cases} A_p E^{-\alpha}, & E_{pL} \le E \le E_{pH} \\ 0, & \text{otherwise,} \end{cases}$$

$$\phi_m = \frac{1}{\sqrt{2\pi^3 m_e}} \, n \, \frac{E}{\theta^{3/2}} \, e^{-E/\theta} \; ; \; \theta = kT \; ,$$

$$\phi_G = A_G E \, e^{-\left(\frac{E-E_0}{\Delta}\right)^2} \; .$$

$\phi_p$ is a power law which represents the low energy flux of electrons backscattered from the atmosphere. $\phi_M$ is a Maxwellian distribution with temperature T which describes the ambient flux level at intermediate and high energies in the absence of auroral enhancements, which are described by a

Gaussian distribution, $\phi_G$. n is the Maxwellian density. We note that the Fontheim relation is for differential number flux, expressed in this paper in units $(m^2 \text{ sec str eV})^{-1}$. For isotropically incident electrons, the corresponding current density is obtained from

$$J = \pi\, e_{el} \int_0^{\infty} \phi(E)\, dE \qquad (2.2)$$

The Fontheim equation has seven parameters which give a bit of freedom in fitting observations. In the following we describe our selection of bounds on the parameters.

## 2.3 OBSERVATIONS AND PARAMETERS FOR THE FONTHEIM FORMULA

Although the DMSP observations are not available to us, we have the studies done by several authors to guide our choice of parameters. These include Hardy, Gussenhoven and Holeman (1985), Meng (1978), Tanskanen, Hardy and Burke (1981), and Hardy, Burke and Gussenhoven (1983). On the basis of the spectra shown in these papers, we derive the following limits for the parameters:

$E_{PL} \sim$ 10-20 eV, $E_{PH} \sim$ 1 keV, $\alpha$: 2.5-4.5
$\Delta$: 1 -10 keV, $E_o$: 5-15 keV
n: $10^5$-$10^7$ $m^{-3}$
kT: 1-20 keV

Rather than specify the coefficients $A_p$ and $A_G$ of $\phi_p$ and $\phi_G$ directly, we introduce the parameters $\rho_p$ and $\rho_G$, which specify the fraction of current in the power and Gaussian portions of the spectrum:

$$\rho_p = \frac{J_p}{J_p + J_m + J_G} \qquad \rho_G = \frac{J_G}{J_p + J_m + J_G}$$

## 2.4 CALCULATION OF SATELLITE CHARGING

The electrons incident on the satellite generate secondary and backscattered currents. The net charging current is found using Lai, Gussenhoven and Cohen (1983), Olsen (1983), and Katz, Parks, Mandell, Harvey, Brownell, Wang and Rotenberg (1977):

$$J^{net} = \pi e_{el} \int_0^{\infty} [1-Y(E)-B(E)]\,\phi(E)\,dE \qquad (2.3)$$

Here Y(E) and B(E) are the secondary and backscattered yields. These functions are determined numerically by the S-CUBED computer program MATCHG. The examples shown here are for a satellite covered with teflon. The code MATCHG (MATerial CHarGing) uses the sophisticated models of secondary electron emission and backscatter developed for the NASCAP code. (Katz, 1978 and Katz, 1986). The integrals for net current are performed numerically using tables of Y and B. For a small object, such as the DMSP satellite, the current collection is determined by conservation of energy and angular momentum of the collected ions. This gives the following relationship between the collected current, $J^{net}$, the satellite potential, $\phi$, and the ram ion current density and energy, $J_{ion}$ and $T_s$.

$$\phi = T_s \left[ \frac{J^{net}}{J_{ion}} + 1 \right] \qquad (2.4)$$

For typical, low earth and polar orbits, $T_s \sim 5V$, where $V_{sat} \sim 8$ km/sec, and $J_{ion} = 1/4\, n_{ion}\, e_{el}\, V_{sat}$.

## 2.5 EXAMPLES

In the following, we describe the kinds of plots that can be made to graphically display charging regimes in terms of the environmental parameters of the Fontheim equation. For these initial studies, we have omitted the power

law contribution to focus on the relative contributions of the Maxwellian and Gaussian distributions. These are the most important at intermediate and high energies. We begin by plotting the Fontheim relation, and show Figures 2.1 and 2.2 for two different Maxwellian temperatures, 1 and 4 keV. The Gaussian is the large peak centered at 8 keV (the value of $E_o$). The plots show the effect of changing the parameter $\rho_G$, while keeping total current fixed. At higher temperatures, the Gaussian nearly always dominates the plot.

In Figure 2.3, we show lines which divide the ($\theta$, $E_o$) plane into charging and noncharging regimes for five different values of the parameter $\rho_G$. The width of the Gaussian distribution, $\Delta$, is held fixed. In the part of the ($\theta$, $E_o$) plane up and to the right (increasing E and $\theta$) of a curve, charging occurs, and does not occur down and to the left.

A family of curves of the ratio of net to total current versus temperature for a series of values of $E_o$ are shown in Figure 2.4. The width ($\Delta$) and relative amplitude ($\rho_G$) of the Gaussian are held fixed in this plot. As the temperature increases, higher values of $E_o$ are required to initiate charging. At a given temperature, the ratio of net to total current increases most rapidly for higher values of $E_o$.

Figure 2.5 gives a different perspective of the same phenomena. In this figure, the same ratio is plotted, but as a function of $E_o$ instead. The curves are for a series of values of temperature. Beyond temperatures of about 13 keV, the curves nearly overlay.

Figure 2.6 shows a summary plot of the charging potentials for a simulated environment. The potential, according to Equation (2.4), for a random sequence of environments is shown as a function of the ratio of total electron and ion currents. For this figure, the parameters of the Fontheim equation were varied according to a uniform probability distribution within prescribed limits that are thought to be representative. The limits are shown on the figure. There is no voltage until the ratio approaches unity, at which point there is an increase to about 130 V for this ensemble of environments.

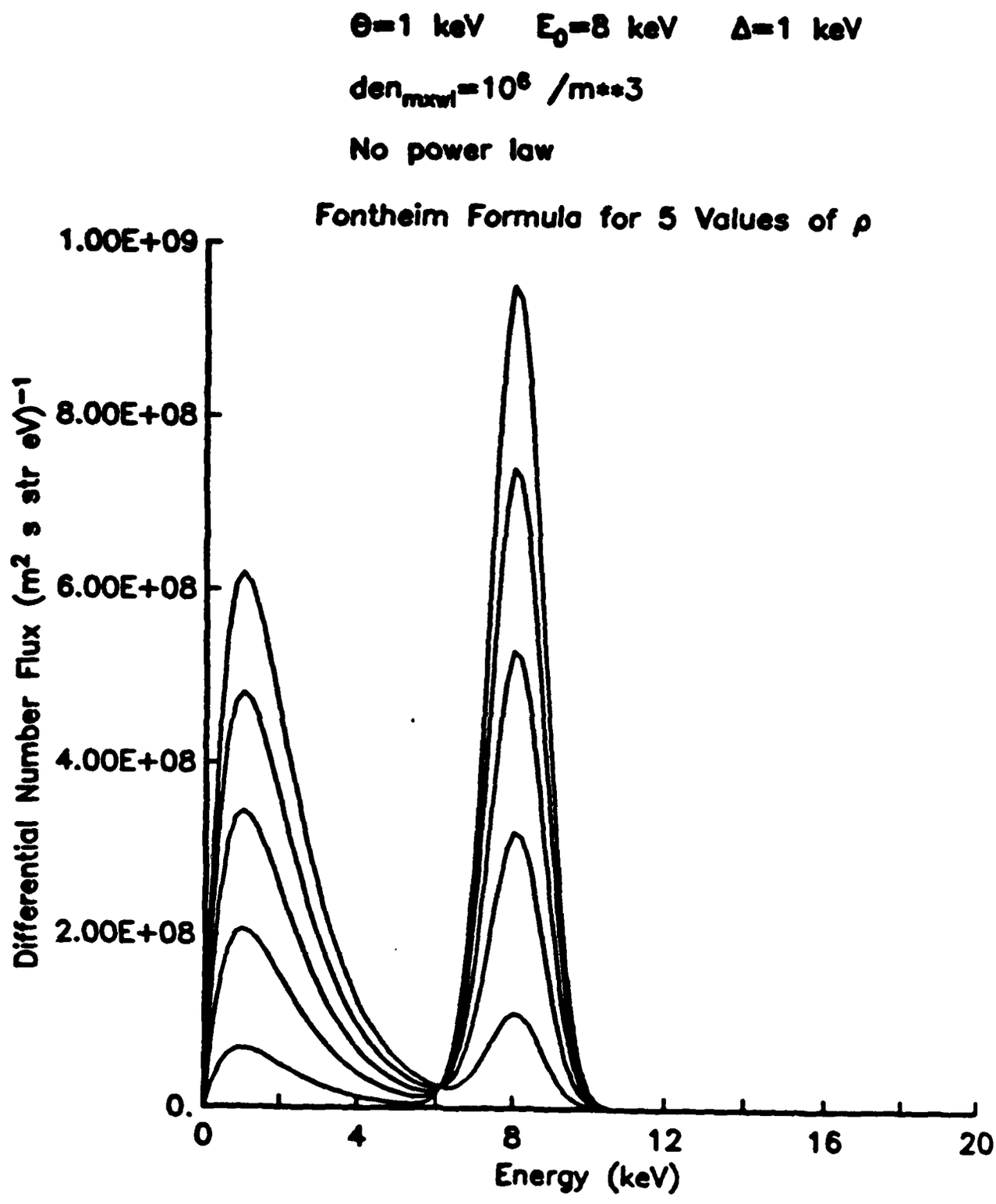


Figure 2.1. The differential number flux described by the Fontheim equation is shown for five values of $\rho_G$: .1, .3, .5, .7, and .9. The curve for $\rho_G$ = .9 has the largest Gaussian peak and for $\rho_G$ = .1 the smallest. The other parameters are given in the heading.

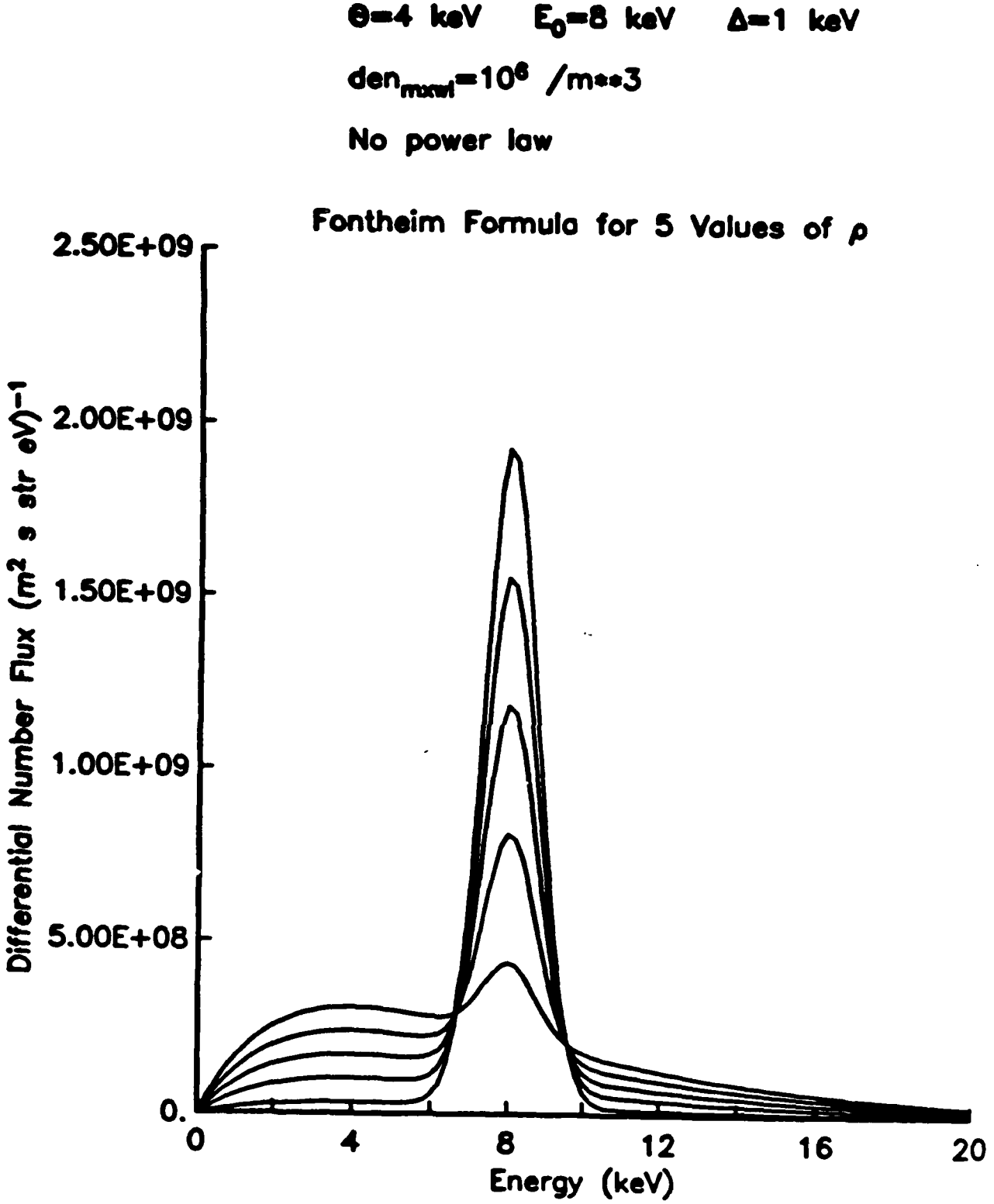


Figure 2.2. The differential number flux described by the Fontheim equation is shown for five values of $\rho_G$: .1, .3, .5, .7, and .9. The curve for $\rho_G$ = .9 has the largest Gaussian peak and for $\rho_G$ = .1 the smallest. The other parameters are given in the heading.

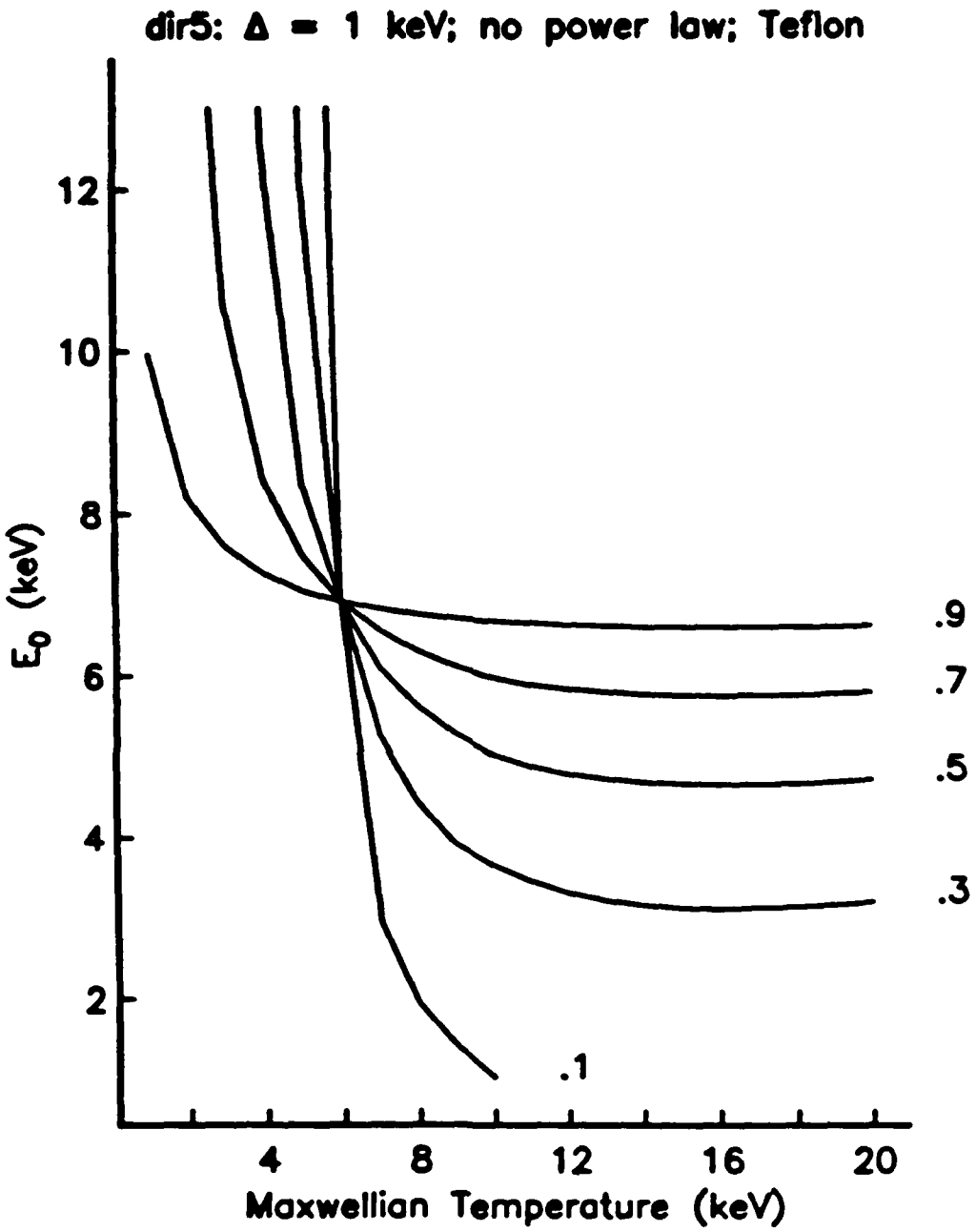


Figure 2.3. The locus of points along which $J^{net} = 0$ are plotted in the ($\theta$, $E_0$) plane for five values of $\rho_G$, shown along the right.

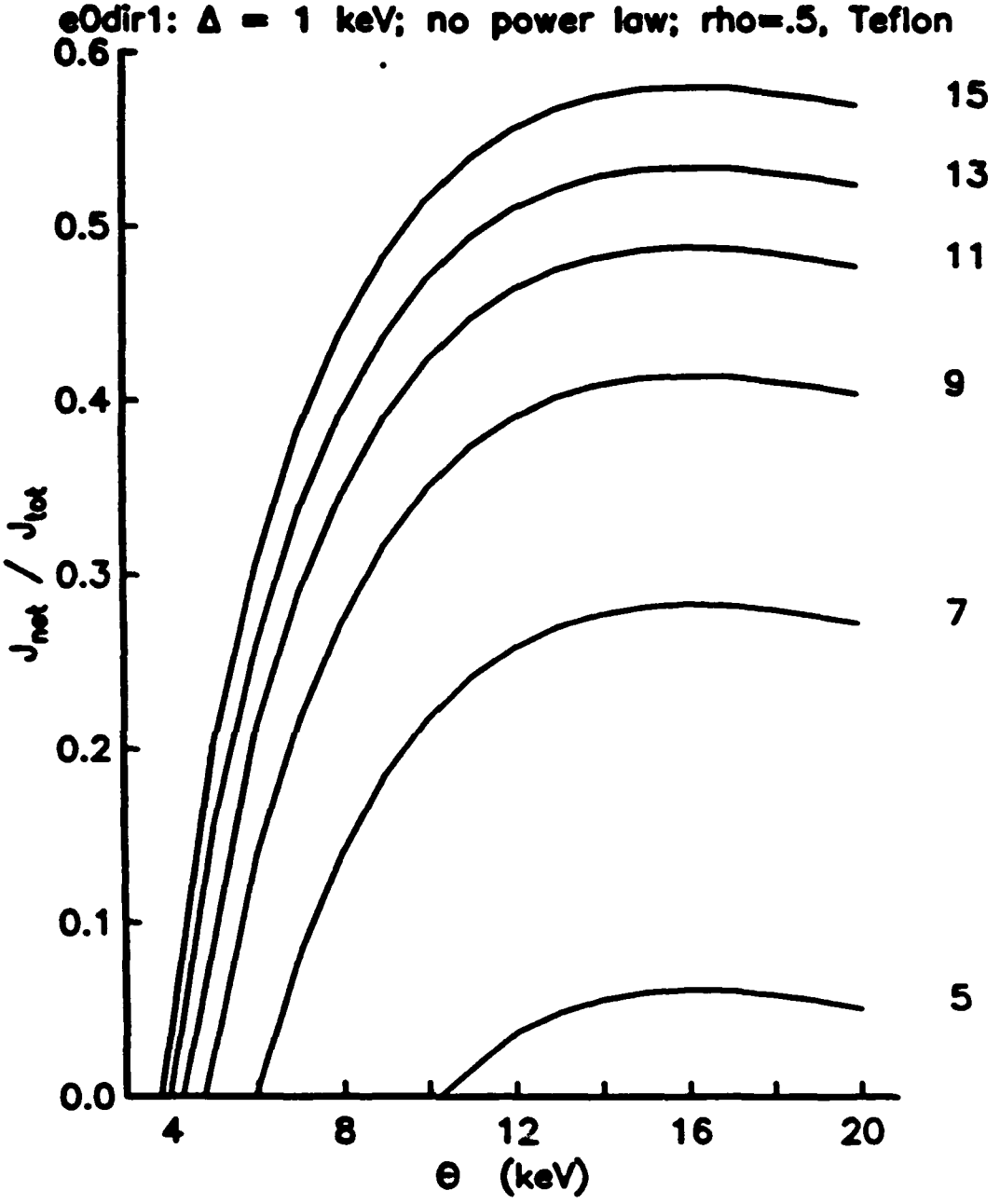


Figure 2.4. The ratio of net to total current is plotted versus Maxwellian temperature for several values of $E_o$, shown along the right.

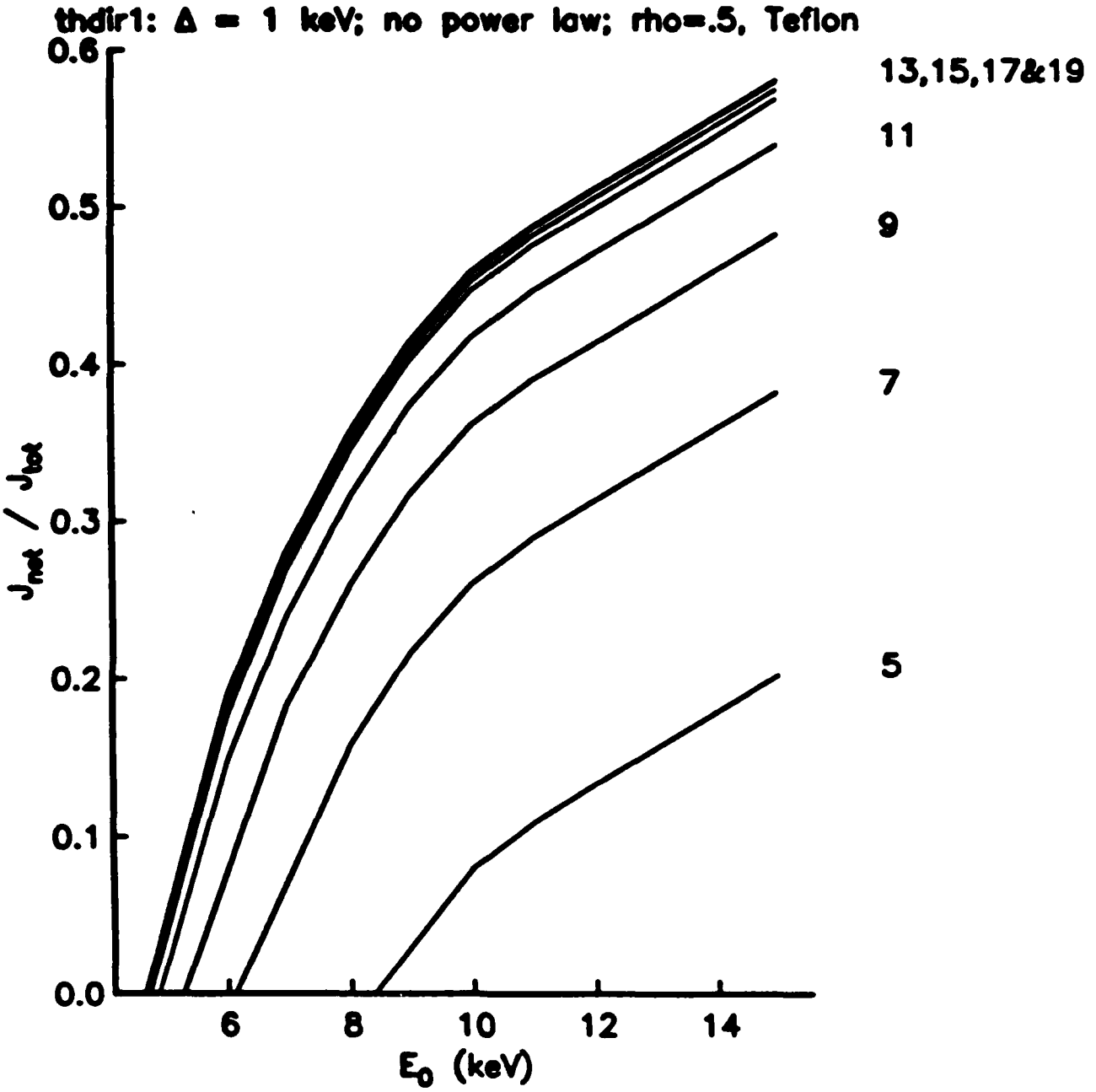


Figure 2.5. The ratio of net to total current is plotted versus $E_0$ for several values of Maxwellian temperature, shown along the right.

An advantage of this approach is that when the observed spectra are fit to the Fontheim formula, a set of physical parameters are found which are fundamental properties of the flux (e.g., Maxwellian temperature, Gaussian center energy). This is a useful result by itself. In addition, plots of the type described in this section can be used as templates to predict charging regimes. The difficulty is that we do not presently have a robust scheme for fitting noisy observations to the nonlinear Fontheim relation. The approach described in the next section circumvents this difficulty.

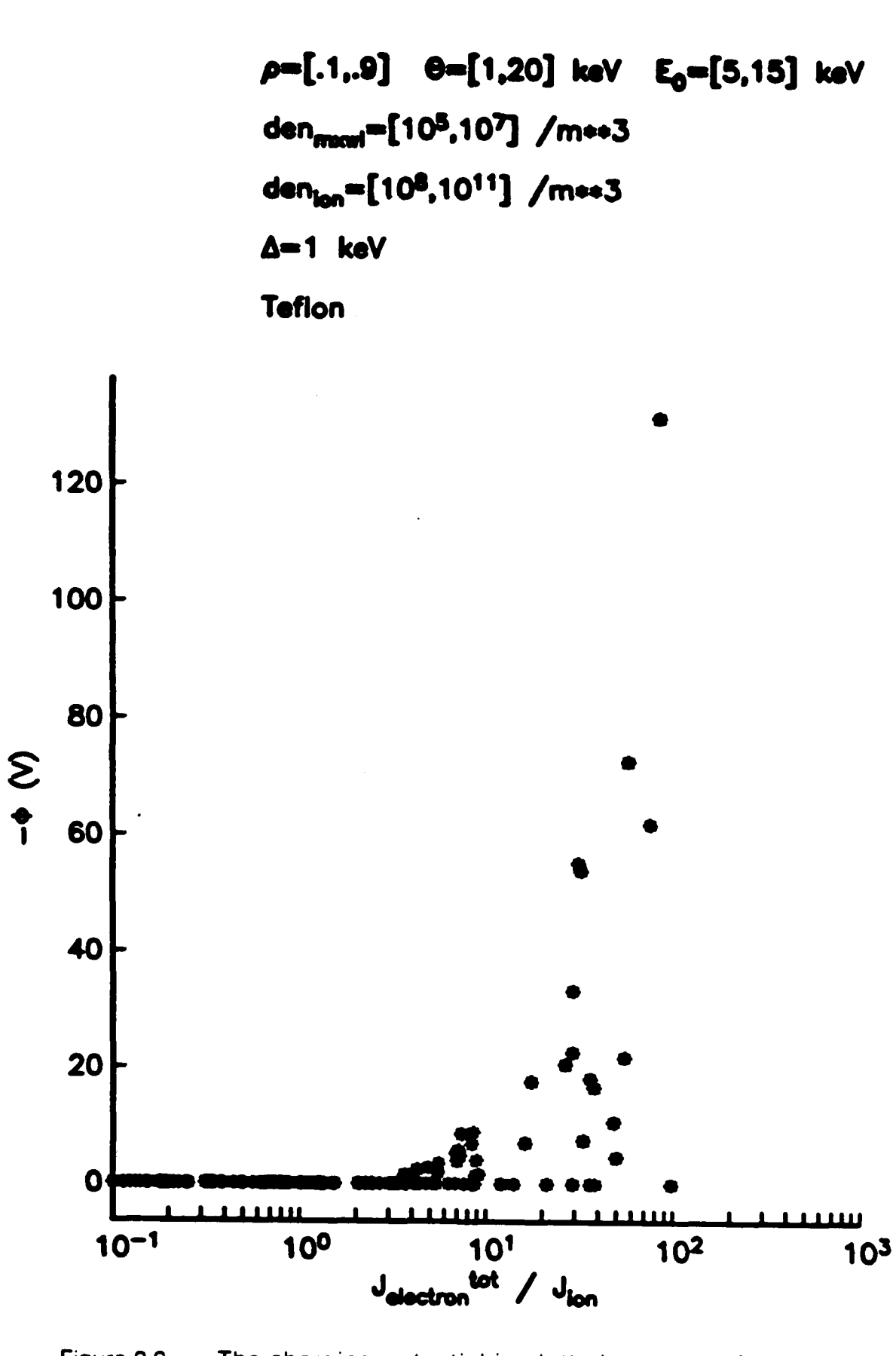


Figure 2.6. The charging potential is plotted as points from a random distribution of environmental parameters.

# III. DIRECT INTEGRATION OF OBSERVATIONS

In Section II, we discussed methods for computing charging potentials in which it was assumed that observed spectra could be fit to analytic functions; in this case, the Fontheim formula. An alternative approach is to compute the charging potential directly from observations. That is, we sum differential fluxes measured by detectors which count the number of electrons in a sequence of energy bands. The counts are treated as discretizations of a continuous flux, which are then numerically integrated with respect to energy to find the total and net fluxes according to Equations 2.2 and 2.3.

Although this procedure is simple, errors can arise from several sources, including those associated with instrument design, numerical methods and the physical models and assumptions upon which the procedures are based. In the following, we investigate the nature of the errors in computing charging potentials which can be introduced by these sources.

## 3.1. SAMPLING

The DMSP detectors are robust and well calibrated instruments so we shall not consider instrument malfunction as a source of error. However, digital data sometimes suffer from dropped bits associated with recording and transmitting. The result is a "glitch" which is typically a datum whose amplitude is much greater from neighboring values, or is identically zero. These can usually be detected by a first difference algorithm or comparing to zero. We shall assume here that these glitches can be detected and removed.

The DMSP detectors sample the flux spectrum at 20 energies whose logarithms are spaced at equal intervals between 1 eV and 30 keV (Hardy, *et al.*, 1984). The geometric factor for the detectors is a instrument gain which may be represented by a Gaussian function centered at the 20 energies. The sampled spectrum at a particular center energy is a continuous spectrum seen through a Gaussian window. We consider here two sources of distortion of the continuous spectrum by the sampling scheme. First, the width of the Gaussian function is

such that important variations in the spectrum are averaged out. Second, the sampling interval may be to large to resolve the spectrum. The logarithmic sampling intervals sample most densely at low energies, so undersampling would affect high energy data most. To assess the distortion, we performed the following numerical experiments. The geometric factor for a collector centered at $E_{ci}$ has the functional form.

$$I_i(E) = \frac{\sqrt{\beta/\pi}}{E_{c_i}/Q} \exp\left[-\beta\left(\frac{E-E_{c_i}}{E_{c_i}/Q}\right)^2\right]$$

where

$$\beta = \frac{1}{2}\ln(2)$$

and $Q = 47$, found by fitting the curves in Figures 9 and 10 in Hardy, *et al.*, 1984. The $i^{th}$ value of the sampled spectrum is then

$$\hat{\Phi}_i(E) = \int_0^\infty \Phi(E)\ I_i(E)\ dE$$

Figure 3.1 compares the values of the sampled spectrum with those of the continuous spectrum, in this case a Fontheim spectrum with an inverted-V spectrum represented by a large Gaussian term. It can be seen that even though the spectrum is changing quickly with energy, the values of the sampled spectrum are quite close to the continuous values. This can be ruled out as a cause of error on the basis of this and similar experiments with other continuous spectra. However, the inverted-V spectrum is under-sampled, which would result in an underestimate of the total electron flux. The errors can be quantified

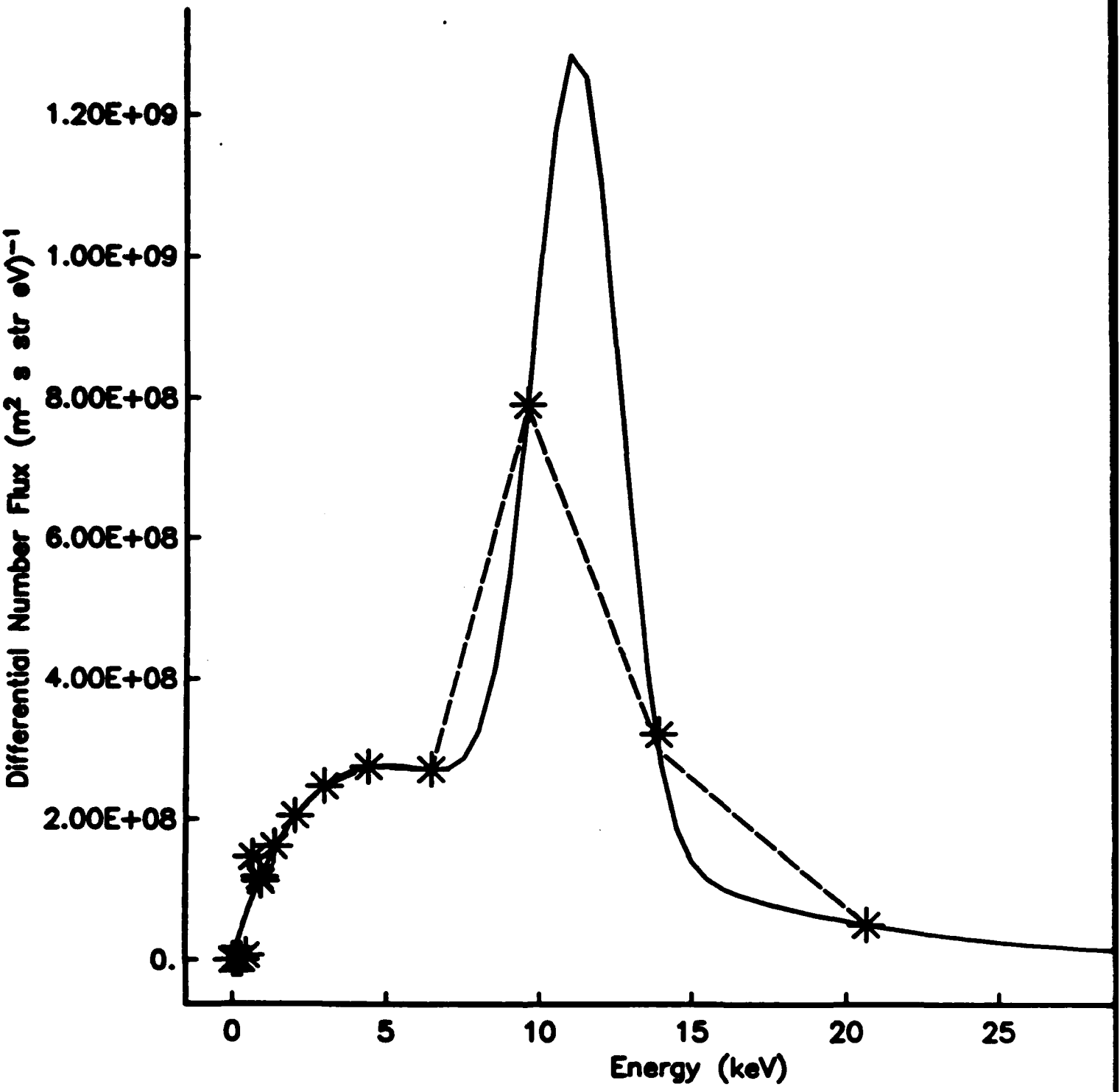


Figure 3.1. A spectrum (solid line) represented by the Fontheim formula is plotted. The Maxwellian density and temperature are $10^6/m^3$ and 5 keV, respectively. The Gaussian scale factor, center energy and width are $10^5/(m^2$ s str eV), 11 keV and 2 keV, respectively. The dotted line connects points on the continuous spectrum sampled at DMSP center energies. The *'s are values as seen through the DMSP collectors.

in this analytic example but to do so with observations is of course not possible as we have no independent estimate of the continuous spectrum. We can only keep it in mind as a source of problems when features such as high-energy peaks are present in the data.

## 3.2. PHYSICAL ASSUMPTIONS AND NUMERICAL PROCEDURES

The programs described here are designed to be tools for analyzing large quantities of data so the techniques are simple and computationally fast. The calculations do not involve the nonlinear, iterative schemes to solve for charging voltage that are used in other S-CUBED charging programs but employ simple methods that perhaps sacrifice some accuracy for speed. The assumptions that go into these calculations are associated with the following:

1. the angular distribution of incident flux,

2. the covering material (type and distribution on the surface), and

3. the sheath distance.

The direction of the incident electron flux enters the calculations in the MATCHG calculation of backscatter and secondary yields. For the examples presented in this report, the fluxes were assumed to be isotropic. Since the yield curves are not strongly affected except at extreme angles of incidence, isotropy is a good assumption for the talk of incidence angles. The total flux estimated from the measured spectrum also depends on the angular distribution of incident electrons which affects the estimate through an areal scale factor. We point out that if information becomes available indicating anisotropy is important, then these effects could be readily included, especially since MATCHG already computes yield curves for beamed electrons.

The covering material determines the proportions of secondary and backscattered electrons. The **charge** program (see Appendix A) incorporates this by reading files written by MATCHG listing yields as functions of energy for each material of interest. These files are described in the manual which

constitutes the appendix of this report. Details of the calculation of yield curves are given in Katz, et al (1977). In the interest of computational speed, a uniform surface covering is assumed and a one-dimensional charge calculation is done. If the satellite has concave surfaces or coverings with strong variations in secondary and backscatter properties, than a three-dimensional approach is warranted. The success of Katz, *et al.*, 1985, in matching calculated charging voltages with DMSP observations using a one-dimensional approach indicates that the assumption of uniform covering is probably justified.

To calculate the sheath distance, we employ the two methods used by Katz, *et al.*, 1985. For the DMSP satellite, they showed that ion collection is orbit limited, while for the larger space shuttle, the mechanism is space charge limited. The **charge** program allows the analyst to specify which mechanism is to used in the calculation. Again, in the interest of computational speed, we have made an approximation to the charging calculation by using only one iteration for voltage. That is, the charging voltage satisfies

$$J_{net}^{ion} + J_{net}^{electron} = 0 \qquad (3.1)$$

where

$$J_{net}^{electron} = \pi e \int_{V}^{\infty} (1-Y-B)\,(1-\frac{V}{\theta})\,\phi(E)\; dE \qquad (3.2)$$

and the ion current is computed using the orbit limited or space charge limited mechanism. To find the voltage V, one computes the net electron current with an initial lower limit E = 0, then finds the voltage which gives an ion current satisfying 3.1. This voltage is then used to compute the lower limit for 3.2 and the processed is repeated until convergence. The **charge** program performs only the first iteration. This is valid as long as the charging voltages are small compared to the electron energies.

The real test of the validity of these assumptions is an extensive comparison of the calculated results to observations. Until this is done, we can only speculate which procedures and approximations are important.

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# APPENDIX A
# A-I. DIRECTORY STRUCTURE AND PROGRAM DESCRIPTION

Data and programs are organized by UNIX directories. In the following, path names will be relative to a main working directory. Within this directory are the following sub-directories: (as shown in Figure A.1).

**charge spectra fontheim instrument sampling yields spectra**

**instrument** and **yields** are data directories, while **charge**, **fontheim** and **sampling** are program directories.

The **charge** program reads spectra and computes currents and potentials for single or multiple events as described in Section II. The **sampling** program is a tool for investigating the effects of sampling continuous spectra by the DMSP collectors (also described in Section III). The **fontheim** programs (see Section II) are used to generate synthetic spectra to exercise and test **charge**.

*We describe the directories' contents and functions below.*

## A.1.1 **charge** PROGRAM DIRECTORY

The **charge** program reads differential flux spectra, removes glitches, smoothes, interpolates and integrates the spectra for total and net electron fluxes. The total integrated fluxes are then used to compute net and total currents and charging voltages. Default parameters are prescribed in a file, and can be changed via an interactive mode. A plot script allows the analyst to compare the smoothed spectrum with the input spectrum.

### A.1.1.1 Program

**charge** ... compute charging potential

Synopsis

**charge -p** <parameter file> **-i**

Description

**charge** reads parameters from the < parameters file > proscribed on the command line, or from the default file **parameters** if **-p** is absent. Further changes to the parameter set can be made through interactive mode, entered by using the **-i** option. If **-i** is not on the command line, interactive mode is not entered, and the program executes.

In the following, we describe the interactive input and then the parameter file. Note that execution does not begin until the interactive command "run" es entered.

### A.1.1.2 Interactive Input

Commands are of the form:

< key word > < value >

where < key word > is a character string and value is an integer, real number, logical variable or character string, depending on the variable being set. Integer and real numbers should contain no imbedded blanks. Logical variables must be **t, .true., f,** or **.false.**. Character strings must contain 80 characters or less. At least one blank must be between < key word > and < value >.

Interactive commands are the following (only the first three letters are required):

**help**

Print menu

**print**

Print current values of parameters

**obsfil** < observed spectra file >

File name of spectra. Details of file structure are given in the **spectra** section of this manual.

**outfil** < output file >

File name for results charging calculations. Details are given below in this section.

**method** < interpolation method >

Method used to interpolate spectra onto energy array used for integration. Options are **linear, spline, hermite and none**. **linear** is a linear interpolation, **spline** is a cubic spline, **hermite** is a monotonic cubic spline, and **none** indicates no interpolation is to be performed. The resulting interpolated arrays contain the original spectra.

**yield** < yield file name >

File name containing backscatter and secondary yields. Details of the file structure are given in the **yields** directory section of this manual.

**dglitch** < true or false >

Deglitch flag.

**sid** < spectrum id >

The string < spectrum id > is compared to identification lines of the spectra file to locate the spectrum the user wishes to process. < spectrum id > may be any sub-string within the identification line. Leading and trailing blanks are ignored, but imbedded blanks are not. The first match in a file is used. The entry **all** indicates all spectra in the file will be processed.

**case** < charging case >

Charging case, either **orbit limited** or **space charge limited**.

**dio** < ion density >

The ambient ion density is used in the potential calculation. Units are $1/m^3$.

**tio** < ion temperature >

The ambient ion temperature is used in the potential calculation. Units are volts.

**rsat** < radius of satellite >

Radius of satellite, in meters. This is used in space charge limited charging case.

**run**

Proceed with calculation

**quit**

Terminate job

**clear**

Clear screen (for Tektronix 4014).

**history**

Print command history.

### A.1.1.3 Parameter File

Parameters not set by interactive mode use those read from the parameter file, described below.

File type

**parameters** ... parameters for **charge** program

Created by

User

Used by

**charge**

The rules for interactive input apply to entries in the file, except that an '=' sign may be inserted between <key word> and <value> (although it is optional). In addition, lines beginning with "#" are ignored by the program and can be used as comments.

Some examples follow.

```
#
# Observations (spectra) file name
#
obsfil = ../spectra/fontheim
#
# Deglitch flag
#
dglitch = t
#
# Energy increment (eV) for interpolations and integration
#
denrgy = 1.e3
```

Several parameters are set in the file that are not set in the interactive mode because they are rarely changed. These are:

**denrgy** = <energy increment>

Energy increment (eV) for interpolations and integration

**pltfil(1)** = <file name>
**pltfil(2)** = <file name>

Output files used by **plot** script to plot input and processed spectra.

**satvel** = <satellite velocity>

Satellite velocity (m/sec) which is used to compute potential for orbit limited case.

### A.1.1.4 Output File

**charge** creates an output file containing the results of the calculation and some identifying parameters.

File type

**output file** ... results of **charge** run

Created by

**charge**

Used by

Analyst

The contents of the output file are a seven-line header followed by the results of processing each spectrum.

The header contains:

**CHARGE file:** <output file name>
<date>
**Observations file:** <input spectrum file name>
**Yield file:** <yields file name>
**Interpolation method:** <method>
**Charging case:** <case name>
<blank line>

For each spectrum, the currents and potential are written as follows.

<spectrum id>
**Computed total and net currents** = <value> <value>
**Computed ion current and potential** = <value> <value>

The units of currents are amps/$m^2$ and those of the potential are volts.

### A.1.1.5 plot script

In addition to this output file , two plot files containing the (reordered) input spectrum and the processed spectrum are written for use by the **plot** script. When multiple spectra have been processed, the last one is written to the plot files. To execute, simply type **plot**. If the names of **pltfil(1)** and **pltfil(2)** are changed in **parameters**, they must also be changed in the plot command file **pltcmd**.

## A-II. **spectra** DATA DIRECTORY

In this directory are the observed differential flux spectra.

File type

**spectra** ... observed differential flux spectra

Created by

User, **senv** or **menv**

Used by

**charge**

The files are formatted files containing one or more concatenated spectra. They are arranged in the following way:

< Spectrum identifier >
**Begin spectrum**
< Number of points in spectrum >
< Spectral Values >
**End spectrum**
< spectrum identifier >
etc.

The < spectrum identifier > is a character string whose length does not exceed 80 characters. The string is used by the **charge** program to locate a requested spectrum within the file. **Begin spectrum** is a key word which denotes the beginning of the spectrum, and similarly for **End spectrum**. The < Number of points in spectrum > is an integer in (i5) format. The spectral values may be in one of two formats, depending on whether the energy values are on the file or will be read from another file in the **Instrument** data directory (Section A-III). In the first case, the format is

< channel number > < energy > < differential flux >

in (i5, 1p2e15.6) format. In the second case, the format is

< channel number > < differential flux >

in (i5, 1pe15.6) format. Additional spectra are appended to the first. The format is determined by **charge** by examining the first spectrum in a file, so that the format should be the same throughout a file. Spectral values have the units $1/(m^2$ sec str eV), and energies are in keV.

## A-III. **Instrument** DATA DIRECTORY

The instrument directory contains files with attributes of the DMSP collectors. Currently, it contains lists of the center or peak energies of the F8 and F10 collectors (called epeaks.f8 and epeaks.f10, respectively), and a file (epeaks.av) in which the averages of the center energies of F8 and F10 are listed. The source of the center energies is Hardy, et al (1985).

File type

**energies** ... DMSP channel numbers and center energies

Created by

User

Used by

**sampling, charge**

The format of these files is:

<header>
**Channel Energy (keV)**

<channel number> <center energy>
•
•
•
•
<channel number> <center energy>

<header> is a character string used for identification. The second line is for readability and is not used. There are 20 center frequencies arranged in the order of Table 2, pg 14, Hardy, **et al**, 1985.

Note that energies are in keV.

## A-IV. **yields** DATA DIRECTORY

The **yields** contain files of backscatter and secondary yields for spacecraft covering materials of interest. The yields are obtained as functions of energy from the S-CUBED program **matchg**.

File type

**yields** ... backscatter and secondary yields

Created by

**matchg**

Used by

**charge, senv,** or **menv**

The files have the following format. There are six header lines which are used for identification only (they are not used by the programs described here), as shown in the following example.

MATERIAL IS gold
ELECTRONS: NE1 = 3.90E+06 ($M^3$) TE1 = 10.100 KEV
IONS : NI1 = 2.80E+07 ($M^3$) TI1 = 0.005 KEV
TABLE GENERATED USING ISOTROPIC INCIDENT FLUX
< blank line >
ENERGY(KEV) EL. SEC. EL. BKSCAT. PR. SEC.

The first line identifies the material, and the next three lines are parameters of the MATCHG run. Data are in the following format:

< energy > < secondary > < backscatter >
•
•
•
•
< energy > < secondary > < backscatter >

The data are read in list-directed (• format) reads.

## A-V. **fontheim** PROGRAM DIRECTORY

This directory contains two program sub-directories for calculating synthetic environments using the Fontheim formula: **sngl_env** for a single spectrum and **mult_env** for multiple concatenated spectra. Two libraries, **intlib** and **rdlib**, contain subroutines used by both programs.

The single environment program can be used to examine the sensitivity of the spectrum to the Fontheim parameters. The net electron current is printed and a plot script makes a plot of the spectrum. The programs in both directories write files which can be read by **charge**.

### A.5.1 **fontheim/sngl_env** PROGRAM DIRECTORY

**senv** Program

Program

**senv** ... compute single Fontheim environment

Synopsis

**senv -p** < parameter file > **-o** < output spectrum file >
**-y** < yields file > **-s** < energy spacing >

Description

**senv** writes a differential flux spectrum to a file which can be read by **charge**. As with **charge**, **senv** reads the values of parameters from a file. The file name can be specified using the **-p** option in the command line, or the default value **parameters** is used.

No interactive mode is available in **senv**. Other inputs that can be specified on the command line are the output file, the yields file and the energy spacing, described below in the description of the parameter file. The script **plot** generates a plot of the spectrum.

**senv** applies an operator which simulates the sampling effect of the DMSP collector on the continuous spectrum (see **sampling** program).

Parameter File

File type

**parameters** ... single environment parameters

Created by

User

Used by

**senv**

Description

The parameter file for **senv** follows the same rules of syntax as the one for **charge**, described above. The variables which can be set in the file are the parameters in the Fontheim equation, file names and calculation parameters. They are described below.

See section II of this report for a description of the Fontheim relation.

**den2** < value >

Maxwellian density in $1/m^3$.

**theta** < value >

Maxwellian temperature in eV.

**gauco** < value >

Gaussian scale factor in $1/(m^2$ sec str eV)

**rhog** < value >

Ratio of Gaussian current to total (see sec 2). If **rhog** < 0, **gauco** is used. Otherwise, **gauco** is computed from the value of **rhog**.

**enaut** < value >

Center energy of Gaussian function.

**delta** < value >

Width of Gaussian function.

**powco** < value >

Power law scale factor in $1/(m^2$ sec str eV)

**palpha** < value >

Power law exponent (dimensionless).

**pcutl** < value >

Power law low energy cutoff in eV (contribution = 0 for energy < pcutl)

**pcuth** < value >

Power law high energy cutoff in eV (contribution = 0 for energy > pcuth)

**qinst** < value >

Instrument Q (set < = 0 if no instrument operator is to be applied)

**spacing** < string >

The energy spacing may be specified by this parameter. Options are **linear**, **log**, and **DMSP**. In **linear** mode, the spectrum is sampled at equal interval (de = 1 keV) from 1 to 30 keV. In **log** mode, the spectrum is sampled at energies whose logs are equally spaced from 1 to 30 keV, approximating the center energies of the DMSP collector. If **spacing** = **DMSP**, center energies are read from the **instrument** directory and used for the calculation.

**yields** < string >

Yields file name

**outfil** < string >

Output (spectrum) file name. If **spacing** is **linear** or **log**, the spectra are written with energies, but if **spacing** = **DMSP**, only the fluxes are written (see **spectra** directory description).

In addition to computing the flux on the specified spacing, **senv** integrates the computed spectrum on a dense energy spacing and writes the net and total currents on the output file header for reference.

## plot Scripts

the plot scripts plot the contents of the file **pltfil**, which is written by **senv** when **outfil** is set to **pltfil**. If **spacing** is set to **linear** or **log**, use the script **plot**. If **spacing** is **DMSP**, use **plot.DMSP** (which reads the ordinate of the plot from the **instrument** directory.

### A.5.2 **fontheim/multenv** Program Directory

**menv** program

Program

**menv** ... compute multiple Fontheim environment

Synopsis

**menv -p** < parameter file > **-o** < output spectrum file > **-y** < yields file > **-s** < energy spacing > **-n** < number of spectra >

Description

**menv** writes multiple differential flux spectra to a file which can be read by **charge**.

The spectra are a random sequence of events where the Fontheim parameters and the ion densities vary randomly within prescribed limits.

As with **senv**, **menv** reads the values of parameters from a file. The file name can be specified using the **-p** option in the command line, or the default value **parameters** is used.

No interactive mode is available in **menv**. Other inputs that can be specified on the command line are the output file, the yields file, the energy spacing and the number of spectra, described below in the description of the parameter file.

**menv** applies an operator which simulates the sampling effect of the DMSP collector on the continuous spectrum (see **sampling** program).

Parameter File

File type

**parameters** ... multiple environment parameters

Created by

User

Used by

**menv**

Description

The parameter file for **menv** follows the same rules of syntax as the ones for **charge** and **senv**, described above. The types of variables which can be set in the file are the parameters in the Fontheim equation, file names and calculation parameters. They are described below. See Section II of this report for a description of the Fontheim relation.

**den2** < lower limit > < upper limit >

Limits of log of Maxwellian density in $1/m^3$.

**theta** < lower limit > < upper limit >

Limits of Maxwellian temperature in eV.

**rhog** < lower limit > < upper limit >

Limits of ratio of Gaussian current to total (see sec 2).

**enaut** < lower limit > < upper limit >

Limits of center energy of Gaussian function.

**delta** < lower limit > < upper limit >

Limits of width of Gaussian function.

**powco** < lower limit > < upper limit >

Limits of power law scale factor in $1/(m^2$ sec str eV)

**palpha** < lower limit > < upper limit >

Limits of power law exponent (dimensionless).

**pcutl** < lower limit > < upper limit >

Power law low energy cutoff in eV (contribution = 0 for energy < pcutl)

**pcuth** < lower limit > < upper limit >

Power law high energy cutoff in eV (contribution = 0 for energy > pcuth)

**qinst** < value >

Instrument Q (set < = 0 if no instrument correction)

**spacing** < string >

The energy spacing may be specified by this parameter. Options are **linear**, **log**, and **DMSP**. In **linear** mode, the spectrum is sampled at equal intervals (de = 1 keV) from 1 to 30 keV. In **log** mode, the spectrum is sampled at energies whose logs are equally spaced from 1 to 30 keV, approximating the center energies of the DMSP collector. If **spacing** = **DMSP**, center energies are read from the **instrument** directory and used for the calculation.

**yields** < string >

Yields file name

**outfil** < string >

Output (spectrum) file name. If **spacing** is **linear** or **log**, the spectra are written with energies, but if **spacing** = **DMSP**, only the fluxes are written (see **spectra** directory description).

In addition to computing the flux on the specified spacing, **menv** integrates the computed spectrum on a dense energy spacing and writes the net and total currents on the output file header for reference. Successive spectra are appended to end of file.

**verbos** < logical variable >

If true, print verbose calculation results. Otherwise, print terse output.

## A-VI. **sampling** PROGRAM DIRECTORY

The **sample** program in this directory allows the analyst to examine the effects of sampling a continuous spectrum, as discussed in section 3 of this report. the analyst may specify a type of function and its parameters and then make a plot showing the function on a finely spaced grid (the continuous function), the function on a coarsely spaced grid and the function as seen by the DMSP collector on a coarsely spaced grid (observations).

Program

**sample** .. examine effects of sampling

Synopsis

**sample**

Description

The **sample** program is interactive, with no command line input. Command options are the following:

**help**

Print menu

**print**

Print current values of parameters

**run**

Proceed with calculation

**quit**

Terminate job

**clear**

Clear screen (for Tektronix 4014).

**qinst** < value >

Instrument Q

**function** < string >

Types of function to be analyzed. Options are **constant, linear, parabola, gaussian** and **fontheim**. For each type of function except **fontheim**, a prompt for the parameters of the function will appear. The user should respond with one or two values, as requested. Because of the large number of parameters in the Fontheim equation, these are read from the file **parameters** when **fun fontheim** is specified. The format and content of the parameter file is the same as the one for fontheim/sngl_env/parameters, except that only the parameters of the Fontheim equation are included.

**plot** Script

**sample** writes the spectra to three files: **outfil.fine**, **outfil.coarse** and **outfil.sam**, which the **plot** script reads and plots. To execute, type **plot**.

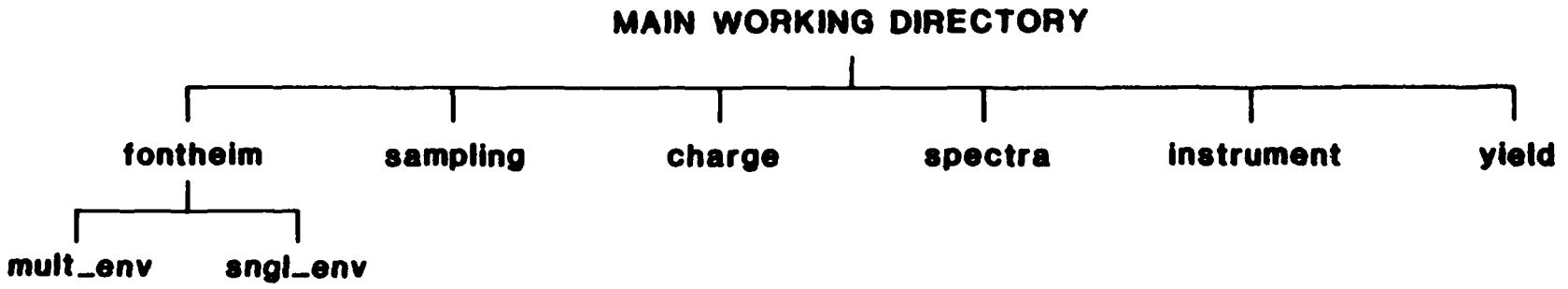




Figure A.1. Directory tree.

END

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