Chapter 5: The Standard IPC (Re)Processing.

1 June 1984

Contents

5.0 Overview

The Imaging Proportional Counter has been described by Gorenstein, et al (TRANS. IEEE Nuc. Sci., NS-28, 869, 1981), and by Giacconi, et al (Ap.J. 230, 540, 1979). The following summary is meant only as a convenient reference for features of the IPC with which users should be familiar. We will purposely gloss over many details and often give simplistic explanations.

The Instrument

The IPC is a gas-filled counter with two "switch-back" pattern wires sandwiching the anode. An incoming photon produces a cascade which induces a pulse in both wires. The pulse height depends on the intensity of the cascade, which in turn depends on the energy of the incident photon and the gain of the counter. The rise time of the pulse lengthens as the pulse propagates along the wire in both directions. The electronics are thus able to assign a (y,z) location (by comparing rise times at both ends of each wire), a pulse height, and a clock time for each event.

Spectral Resolution

The entrance window of the IPC has been coated with "Lexan" to absorb the UV. The window itself absorbs X-rays in the range 0.28 to 0.5 keV, and the mirror ceases to reflect X-rays above about 4.5 keV. The discriminators which measure pulse height encode the information on the basis of 32 pulse height channels (0-31) which, for most subsequent purposes, have been reduced to 16 (0-15). That is 0 and 1 become 0, 2 and 3 become 1, etc., although channel zero is not used because of excessive electronic noise. Throughout subsequent data processing channel specification will be via a 5-digit octal number:

	(low)		Energy		(high)
PH Channel	1 2 3	4 5 6	7 8 9	10 11 12	13 14 15
Contributes	4 2 1	4 2 1	4 2 1	4 2 1	4 2 1
Octal Flag	7	7	7	7	7

e.g. Channel 7 and 11 only would be 00420K.

To assign an energy to the incident photon, we need to know the detector gain which is a function of high voltage and gas composition (vary with time) and irregularities in the wire spacing, etc. (vary with position). The temporal dependence is defined by "BAL", the PH bin (0-31) at which the pulse height distribution for the on-board, calibrator (radioactive aluminum) peaks. Only the central 4' x 4' of the IPC has been accurately calibrated with a celestial source for the positional variations of gain. A less accurate correction map derived from pre-flight calibration data is used for the rest of the field. In REV1 processing, each event has a "PI channel" defined as well as a PH channel (PI standing for pulse independent, i.e. binned according to energy). This PI binning incorporates both the temporal and spatial gain corrections.

Spatial Resolution

The Point Response Function (PRF) of the IPC is a quasi-Gaussian function with low level wings at large distance (due to mirror scattering). The size of the core (Gaussian part) is determined by how accurately the electronic processor can assign the correct location to each event. As the pulse height diminishes (lower gain or softer photons) the S/N worsens and photons are assigned locations over larger and larger areas, even though they actually arrived at one location. The broad wings of the PRF, however, are caused by small scale imperfections on the mirror. These cause occasional but large deflections, which preferentially affect higher energy (shorter wavelength) photons.

A plot of FWHM of the core as a function of PH channel is shown in Figure 5.1.

Timing

Time resolution is 63μ sec; the telemetry limit is 125 cts/s ("primary science" channel), which causes a "Poisson" dead time of ≃4% for fields without very high count rates.

Ghost Images

During pre-flight calibration, it was determined that a strong source outside the field of view but within 2° of the optical axis could produce (ring-like) features within the field. Although no unambiguous occurrence of this effect has been documented during the mission, we reproduce here a table of Effective Area of the mirror at 0.25 keV as a function of distance from the field center (at a position angle of 45° in detector coordinates).

Table 5.1

Off-Axis Angle (arc min)	Effective Area (cm^2 at 1/4 keV)
0	104
40	21
42.4 = "Masked out" edge	
45	17
50	6
53.7 = Physical field-of-view edge	
55	1.7
60	1.3
65	0.8
70	0.6
75	0.7
80	0.5
85	0.2

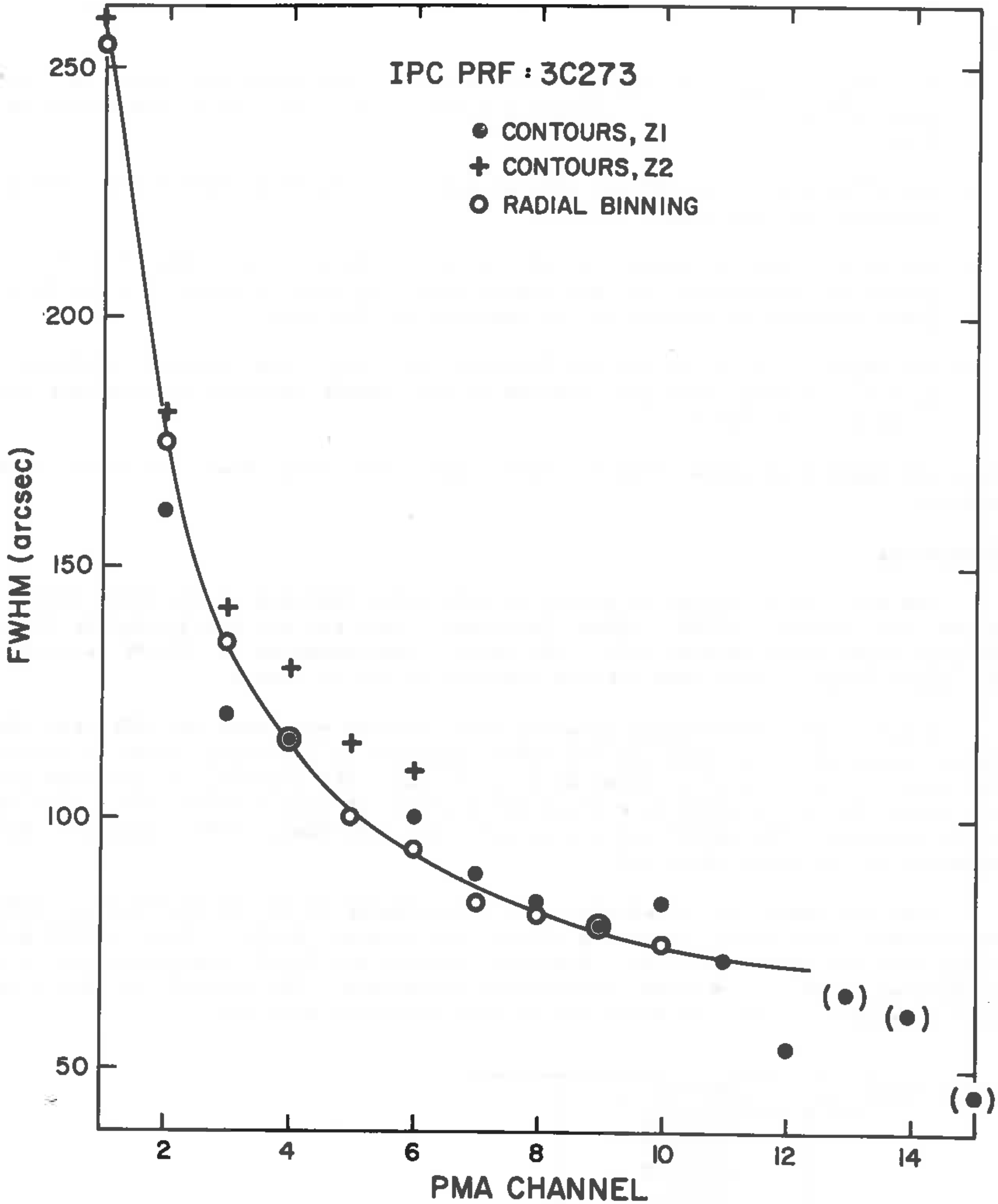

IPC PRF : 3C273
CONTOURS, Z1
CONTOURS, Z2
RADIAL BINNING
FWHM (arcsec)
250
200
150
100
50
2
4
6
8
10
12
14
PMA CHANNEL

Figure 5.1

100	0.06
>112	0

The use of IPC data outside a radius >16 arcmin is fraught with difficulties:

Ribs

1) The ribs are not centered on (Y=511,Z=511); the geometric center of the ribs actually lies at (Y=515.3,Z=523.7) in a non-ASPECT-corrected IMG file.

2) The effective "size" of the ribs is somewhat dependent upon x-ray energy (because the cone angle is).

3) The gain of the detector, which varies widely across the field, is generally depressed in the region near the ribs (because of electrical field distortions caused by the presence of the ribs.

4) The IMAGE files smear out the position of the ribs because different detector orientations are combined by the ASPECT solution in creating the files in (α,δ) space.

As a consequence of these effects, data near the ribs must be used with caution.

Processing

The E.O. data stream is broken up into time segments of variable length. These are called "HUTS" (HEAO Universal Time) and are designated by their initial major frame number (±1). The major frame duration is 40.96 seconds. The major frame counter was started somewhat prior to launch.

A particular observation normally will contain more than one HUT, but the first phase of the production run (PRD) operates on individual HUTS to obtain the Aspect solution and performs data screening. The sequence of programs run is shown below followed by a brief description of each element and a list of files produced. The MERGE processing puts the individual HUTS together and operates on the whole data set.

Once the image is "constructed," a measurement of the background is made to determine what count threshold should, on average, yield 1 false source per field from the DETECT program. Discrete sources are found, and positions are calculated with a maximum likelihood algorithm. The methods of obtaining source parameters will be described in the following sections.

INPUT PHASE

PRDSYM
MINICAT
ADDBASE
PUPDATE
HSKPNG
PUPDATE
PCGDURA

HUT PROCESSING	GET_EPH_MAG_DATA	CALCULATING ASPECT SOLUTION	(A)
	ASPECT1		
	NEWBORE		
	ADDBASE		
	QLPLT		
	ASPECT2		
	ASPECT3		
	ASPECT4		
	IPC_SCREEN	MAKING IMAGE	(B)
	IPC_POSITION_CORR1		
	IPC_POSITION_CORR2		
MERGE PROCESSING	RDBAL		
	IPC_PI_CORR		
	SELECT_TGR		
	SELECT_DATA		
	MAKE_SORT		
	MAKE_IMAGE		
	MAKE_CAH_CAT	SOURCE DETECTION	(C)
	IPC_EXPOSURE		
	IPC_FIELD_BACKGROUND		
	L_ROUGH_POSITIONS		
	FINE_POSITIONS		
	XDETECT		
	IBKGD_MAP		
	ROTPROD		
	ADD_MAPS		
	IMRUFF		
	MRESOLVE		
	MFINE_POSITIONS		
	LIM_SEN		
	MATCH_SOURCES	SOURCE ANALYSIS	(D)
	CAT_UPPER_LIMITS		
	IPC_SOURCE_FLUX		
	IPC_SOURCE_EXTENT		
	RDCAI		
	BAL_HISTO		
	GRADSPEC		
	GRADSPEC_PLOT		
	MAKE_ISF		
	IPC_TIMING_CHISQ		
	GET_EPH_TCOR_DATA		
	BARYCENTER_TIME_CORR		
	APPLY_TCOR		
	IPC_TIMING_FFT		
	IPC_PRINT_DATALOG	OUTPUT	(E)
	IPC_PRINT_SOURCES		
	LIM_SEN_OUT		
	IPC_PRINT_PROPERTIES		
	LIST_MINICAT		
	GET_CONTOUR_LEVELS		
	HEAOMAP		
	GZCONT		

HUT PROCESSING

INPUT PHASE

PRDSYM	Creates Processing Directory with .PCG file, .Info file, Symbol Table and Links to .PRD Files.

HUT PROCESSING

MINICAT	Gathers star catalogue info. Creates .SCAT and .CAT Files.
ADDBASE	Extracts raw FIDCAL Info from Database.
PUPDATE	Updates .PCG File with FIDCAL on/off times.
HSKPNG	Uses .ACD File to update .PCG File with a) Status of: (i) Voltage (on/off) (ii) Filters (iii) SAAD (iv) Grating (v) BOD b) Creates .QPI File with BOD SAAD and Filter Values to be Plotted.
PUPDATE	Updates .PCG File with Results of Housekeeping Run.
PCGDURA	Calculates Instrument Calibration Durations.
GETEPHMAGDATA	Creates MAG File containing Earth Blocking and magnetic field information from Ephembase.
ASPECT1	Checks Aspect Data for each minor frame for validity. Applied calibration correction to tracker and gyro data.
NEWBORE	Creates .BSD File containing processed FIDCAL values.
ADDBASE	Writes processed FIDCAL values into Database.
QLPLT	Creates plot of Aspect solution.
ASPECT2	Produces Aspect solution for intervals when star trackers were locked on two guide stars; folds with gyro data.
ASPECT3	Used to augment ASPECT2 when star trackers not locked on guide stars; identified other stars tracked.
(MAPMODE) ASPECT4	Uses stars identified by ASPECT3 to produce result similar to ASPECT2.

IPC_SCREEN

Performs initial screening of production data; creates .TGR, .XPR, .HVS, .QPI Files, checks for IPC calibration data.

IPC_POSITION_CORR1

Begins the process of correcting photon positions and timing.

IPC_POSITION_CORR2

Finishes process of correcting photon positions. Creates CAL.XPR File for calibration data.

MERGE PROCESSING

RDBAL :

Extracts BAL data from data base and interpolates.

IPC_PI_CORR

Purpose:

Does the PI binning for data in an XPR file. This program can be run more than once on an XPR file because only the Pi bin datum for each photon is overwritten.

SELECT_TGR :

Function:

This program will read one or more input TGR files and screen them according to the parameters in the parameter file. The rejected time intervals are flagged. The time in the accepted intervals is summed. A record of the conditions is saved in the individual HUT QPI files. The updated merged header and each component header with the corresponding GOOD or ON time is also saved in the merged header file which will be created. Also an SDF file will be created with a universal header, the two parameter blocks and one source header block. This file will be mostly zero at this point but will be added to by subsequent programs.

Inputs:

IPC.PF.
EINSTEIN.PF.
One or more timing gaps file (-.TGR) and the corresponding QPI files. If more than one then as MLST file is used as input with a global /L.

Outputs:

An update QPI file. (.QPI)

A Merged and updated timing gaps file. (-.TGR)
A Merged header file. (.MHDR)
An SDF file. (.SDF)

SELECT_DATA :

Function:

This program will read one or more input XPR files and screen them according to the accepted times in the TGR file. The X-ray data during rejected time intervals is discarded. The data during accepted time intervals is then screened by the spatial mask, and the accepted data is written to the merged XPR file. A record of the primary and secondary counts are saved in the individual HUT QPI files. The merged header and each of its component headers is updated with the primary science information. Parameters are updated in the SDF file. Also the TGR file is screened again for CLEAN time. A record of primary and secondary science for CLEAN intervals for each HUT is saved in the CLN file. This is needed later for XDETECT and MDETECT.

Inputs:

EINSTEIN.PF.
IPC.PF.
One or more raw X-RAY data files (-.XPR) and the corresponding QPI and secondary science (SS) files. If more than one, then an MLST file is used as input with a global /L.
A merged TGR file.
A merged header stub. (.MHDR)
An SDF file stub.

Outputs:

Updated QPI files for each HUT. (.QPI)
A Merged and updated XPR file.
An updated Merged header file. (.MHDR)
An updated SDF file. (.SDF)
A clean file. (-.CLN)

MAKE_SORT

Function:

Reads and XPR file and creates a sort (SRT) file.

Inputs:

MAKE_SORT.PF the parameter file for MAKE_SORT. It is located in :HUTIL.
-.XPR old or new XPR file. (If new XPR files are used, then the corresponding HDR files are also needed.)

Outputs:

-.SRT the sort file.

MAKE_IMAGE

Creates an image file from a sort file. The program reads the file containing energy levels when IPC has been specified. This file is an array which tells the program how to compress 32 energies into 16 energy bins. The first 32 words tell how to compress when sorting by PI bins, while the second 32 words compress via PHA bins. Currently, energies Ø and 1 go to bin Ø; energies 2 and 3 go to bin 1; 4 and 5 go to bin 2; etc.

MAKE_CAH_CAI

Purpose:

To create constant aspect histograms for use in making exposure map. Also, constant aspect time intervals are compiled and saved.

Inputs:

- A list file of HUTS (e.g. MLST in production processing). - An aspect solution file for each HUT on the list. - A merged TGR (timing gap record) file.*
- A component header (MHDR) file.*

*The two merged files must contain information pertinent to the HUTs named on the MLST.

Outputs:

- A constant aspect interval (CAI) file for each HUT.
- A constant aspect histogram (CAH) file for each HUT.
- The component header file is also updated.

IPC_EXPOSURE

Purpose:

To fold the IPC geometry information with the aspect solution in order to produce an IPC exposure file. The exposure file is a 256x256 word scaled integer array with a header of 256 words.

IPC_FIELD_BACKGROUND

Purpose:

Calculates IPC background in three PI-bands (soft, hard and broad). ALso constructs PI and PH histograms.

L_ROUGH_POSITIONS

L_ROUGH_POSITIONS is a program which reads an image file and slides a detection window over the data. Any location with a signal to noise ratio above a given threshold is marked and included in the centroid calculation. The rough Y and Z positions are output to the RUF file and passed on to the FINE POSITIONS program.

Inputs:

IPC.PF.
EINSTEIN.PF.
An image file to be analyzed.
The corresponding SDF file created by IPC_FIELD_BACKGROUND.

Outputs:

A scratch file for each PI-BAND containing the rough Y and Z positions for each detection.
An SDF file updated with the parameters used.

FINE_POSITIONS

Purpose:

To calculate fine positions of sources.
Kill sources which do not meet certain criteria.
Calculate probability that source strength is non-zero.
Calculate position confidence regions.

Input:

Image file. (.IMG)
Rough source file. (.RUF)
SDF file. (.SDF)
Exposure file.

Output:

Fine source file. (.FYZ)

XDETECT

Function:

For each PI-BAND subtract the Ldetect source cts. Using the clean SS background data, predict the image counting rate. If this exceeds the observed rate, signal extended or anomalous emission.

Inputs:

Ldetect fine positions (-.L.FYZ) - This is the output file from fine positions in LDETECT.
SDF file - Only the first four blocks of this file are used to read and save the parameters.
EXP file - The exposure map file.
IMG file - The image file.
IPC.PF.

EINSTEIN.PF.
XDETECT.PF.

Outputs:

SDF output source file - This is the answer file with the four-block header in which the SDF source header has been updated with the CLEAN information and ANOMALOUS emission information.

IBKGD_MAP
ROTPROD
ADD_RMAPS

Create one background map for each PIBAND (soft, hard, broad) for each sequence.

LIM_SEN
LIM_SEN_OUT

Compute a minimum detectable flux for a 4 sigma source and for a 5 sigma source for each energy band.

IMRUFF
MRESOLVE
MFINE_POSITIONS

A sliding window technique is used to search for sources above threshold in any given image. Parameters used (e.g., detection cell size) have been optimized for point-like sources.

MATCH_SOURCES

Function:

Read the input fine position file(s) and eliminate duplicate positions within each band.
Match positions between different PI bands and detect methods using the hierarchy given in the parameter file.

Inputs:

Ldetect fine positions (-.L.FYZ) - This is the output file from fine positions in LDETECT.
Mdetect fine positions (-M.FYZ) - This is the output file from fine positions in MDETECT.
SDF input stub - Only the first four blocks of this file are used to read and save the parameters. Any sources already in this file from a previous run of MATCH_Sources will be lost.

Outputs:

SDF output source file - This is the answer file with the four-block header from the input stub and all the composite and component records produced by the match.

CAT_UPPER_LIMITS

Purpose:

To match X-ray sources with catalog sources and compute upper limits on flux and counts/sec.

IPC_SOURCE_FLUX

Purpose:

To calculate hardness ratio, off-axis-angle, vignetting correction, screened background PH spectrum, screened background PI spectrum, net PH spectrum, net PI spectrum, cell counts by PI band, cell background counts by PI band, corrected count rates by PI band, source flux by PI band, all related errors, and component source spectral information, cell counts, background counts, net cell counts, L thresholds, M thresholds, signal-to-noise ratio, and all related errors.

IPC_SOURCE_EXTENT

Program to calculate extent and to get radial PHA distributions for each source in SDF.

Input files:

.SDF/S file - find normalized background information.
write IPC parms.
get source number and center.
.IMG/I file - read counts plus PHA.
IPC_SOURCE_EXTENT.PF.
IPC.PF.

Output files:

.RAD/R file - write counts,radius(arcmin), density(counts/arcmin.sq) for 10 annular bins for maximum of three bands.
.OUT/O file - printable file.

RDCAI

Calculate interpolated BAL values during constant aspect intervals for use by GRADSPEC.

BAL_HISTO

Purpose:

To make the BAL HISTOGRAM for use by GRADSPEC.

Output file:

.BHS.

GRADSPEC

Purpose:

Accepts IPC pulse height data and uses specified model spectrum type to determine the model parameters by the minimum chi-square technique. This chisq minimum is found with the gradient search algorithm(CURFIT).

MAKE_ISF

Purpose:

To make individual source files from an XPR file.

IPC_TIMING_CHISQ

Program to detect substantial non-periodic variability. Calculates chi-square of model of constant source intensity.

Input files:
.LST/I - a list of .ISF file names for a single observation.
.ISF files named in .LST file.
.TGR/T, used to find good time intervals.
.SDF/S, used when running on-line to get total number of sources detected in the field.

Output files:
.OUT/O file, a printable file.
SDF file when running on-line, results for each source are stored in the file.

GET_EPH_TCOR_DATA

Extracts ephemeris data for the sun, jupiter, saturn, and the satellite from the ephemeris data base. The output files will provide the input data for BARYCENTER_TIME_CORR.

BARYCENTER_TIME_CORR

Uses the sun, jupiter, saturn, and satellite ephemeris data to compute the barycentric timing correction once per major frame. (The effect of the moon is included in the data for the run.) The output file is the TCOR file.

APPLY_TCOR

Applies the barycentric timing correction contained in a TCOR file to the photon times in an input ISF file. The output file contains the corrected times and is called a CSF file.

IPC_PRINT_DATALOG

Function:

Creates printable TGR (timing gap record) listing file from merged TGR file.

IPC_PRINT_SOURCES and IPC_PRINT_PROPERTIES

Function:

This routine will read the SDF file and a few other optional information files and give all the information about the observation in addition to basic information about the sources detected.

Inputs:

IPC_PRINT_SOURCES.PF.
Spectral file (from GRADSPEC.
SDF file name.
COF file (from catalog matching).
RAD file (from IPC_SOURCE_EXTENT).

Outputs:

Output listing file.
Note: The listing file will append to an existing file because this program is intended to be run as a companion to IPC_PRINT_SOURCES and provide additional information.

GET_CONTOUR_LEVELS

HEAOMAP

Purpose:

To create plot of known star positions (.MCPL).

GZCONT

Purpose:

To make contour plot of detected sources in field (.SCONT).

DESCRIPTION OF CONTENTS

INPUT FILES	
ASP - .PRD	Raw Aspect Data.
IPC - .PRD	Raw Science Data.
OUTPUT FILES	
FILE	
ASP - .PRN	Aspect Solution (text).
ASP - .PRD	Aspect Solution -
.CAT	Part of Master Star Catalogue that lies in IPC field of view.
.SCAT	Star Catalogue Information relating to tracker fields.
.PLST	PCG Information List.
.QPI	Plotting Information.
ASP - .QPLT	Aspect Strip Plot.
.SS	Secondary Science Data.
.BKB	Data for Future High Background Analysis.
MERGE	
.MLST	List of Merging Huts.

.XPR	Further screened compressed photon information, with GAPMAP and aspect correction applied.
.HDR	Information relating to .XPR file.
.MPT	Aspect correction (exposure) maplet.
.IMG	Image.
.HLST	Star Catalogue Information (text).
.MCPL	Catalogued Star Plot.
.SCONT	Contour Plot of Detected Sources.
.SDF	All Source Information, Locations, Counts, etc.
.ISF	List of source photons extracted from merged XPR file (with timing correction applied) (one for each source).
IPC - .QPLT	Science Strip Plot.
.EXP	Exposure File.
.UPD	OCA Update Information.
.OUTPUT	Text File of Program Outputs.
.MHDR	Merged header and component headers.
. XPR	List of photons in chronological order.
.SPEC	GRADSPEC output file.
.RAD	Radial distribution from extent.

The new format for the IPC reprocessing has been designed to produce a self-contained output. Most of the descriptive information necessary to understand your results is contained in section headings and in the notes to the tables. This User's Manual provides more detail but does not attempt to reiterate all of the descriptions given in the PRD output. A third level of detail resides in the IPC SPECS, available at the CFA.

5.1 Field Data Summary

The term "Nominal" for position and roll angle means the value preselected for the observation from the Detailed Observing Plan (DOP). The "Binned" values refer to the data after processing. If the binned position differs from the nominal target by more than 3 arcmin, a warning message is included on the title page.

The total observation length is (STOP TIME--START TIME); the Net time in the processed image is that part of the observation during which the IPC was collecting "useful" data (see 5.13, 5.14, and 5.15); and the LIVE TIME incorporates the "live time correction" (LTC). The LTC corrects the time for the counts lost by the finite count rate capacity of the telemetry. If your observation contained a source which dominated the field count rate AND was not of constant intensity, see IPC SPECS, Sec. 2.1.1.

"<u>Clean data intervals</u>" are those times during which there should be little contamination from X-ray "reflections" from the bright Earth, from the South Atlantic Anomaly, etc. This concept was devised to make a global test for extended or anomalous emission: "XDETECT," and to improve quality of science data in general. The viewing geometry status (described in 5.14) is specified here by GOOD (VG=3), BETTER (VG=2), and BEST (VG=1). The composition of CLEAN DATA is given both in terms of time and fraction of counts.

<u>Background, Count Rates, and Extended Emission</u>

The summary of XDETECT follows the "Number of compact source" on the field data page and is mostly self explanatory. The image rates (count/livesec./sq. arcmin) are given for the three spectral bands (Field Background). XDETECT uses total field count rates during "clean intervals" after LDETECT sources have been subtracted. It was designed to isolate extended emission which makes a significant contribution to the total count rate (e.g. some supernova remnants and clusters of galaxies) and to identify sequences which contain bright point sources.

XDETECT uses the total counts from LDETECT sources to determine whether a bright source is present. If the total LDETECT source count rate in any band exceeds a rate of 0.6 counts^{-1}, MDETECT is not run for the sequence.

For each PI band, XDETECT predicts the source-free image rate from the guard counter events and coefficients determined from background calibrations. It compares these predicted values to the observed image rates and classifies the extended emission in each band according to the following criteria.

<u>Excess Image Rate E</u>	<u>Extended Emission Classification</u>
$E < 0.25$ ct s^{-1}	Absent
$0.25 \leq E < 0.50$ ct s^{-1} and E significant at 3σ level	Possibly Present
$0.50 \leq E$ and E significant at 3σ level	Definitely Present

If extended emission is present in more than one band <u>or</u> if extended emission is present in one band and possibly present in one or more other bands, MDETECT is not run for the sequence. MDETECT may be run for sequences in which extended emission is classified as only 'possibly present'. In these cases, prominent warnings are displayed in the source summary and MDETECT sections of the output.

All exceptional conditions for bright sources and extended emission are displayed in the Field Summary, Source Summary, and MDETECT sections of the output

The Count Rate Summary gives the total counts and counts per second (net on-time) for (a) the processed image; (b) the Masked Out counts during the same interval (i.e. the field edges); and (c) three count rates from the "secondary science": total events detected by IPC electronics, Guard Counter events (background), and Valid events ("good" events after on-board validity checking).

The full IPC field is 76′ x 76′, but the Mask accepts only the inner 60′ x 60′ because the edges are heavily contaminated by particle events. Under typical operating conditions, ~60% of the valid image counts are in the Masked Out edge, and ~40% fall within the final processed image. Less than half of these final events are within the energy range used for source detection.

To obtain the "time averaged BAL," the BAL from each HUT is weighted by the ON TIME during the HUT.

5.2 Source Summary

Qualification and Merging

Details of source detection methods will be described in the following two sections. However, it is convenient here to outline the overall scheme of isolating sources. In Fig. 5.2 we schematically show the construction of the source list. The MERGE of LDETECT and MDETECT sources depends on a parameter, here called DS (for delta sigma):

$$DS = 3 * (Sigma_1^2 + Sigma_2^2)^{1/2}$$

where $Sigma_1$ and $Sigma_2$ are the uncertainties (including systematic terms) associated with the two positions being compared. The MERGE proceeds as follows:

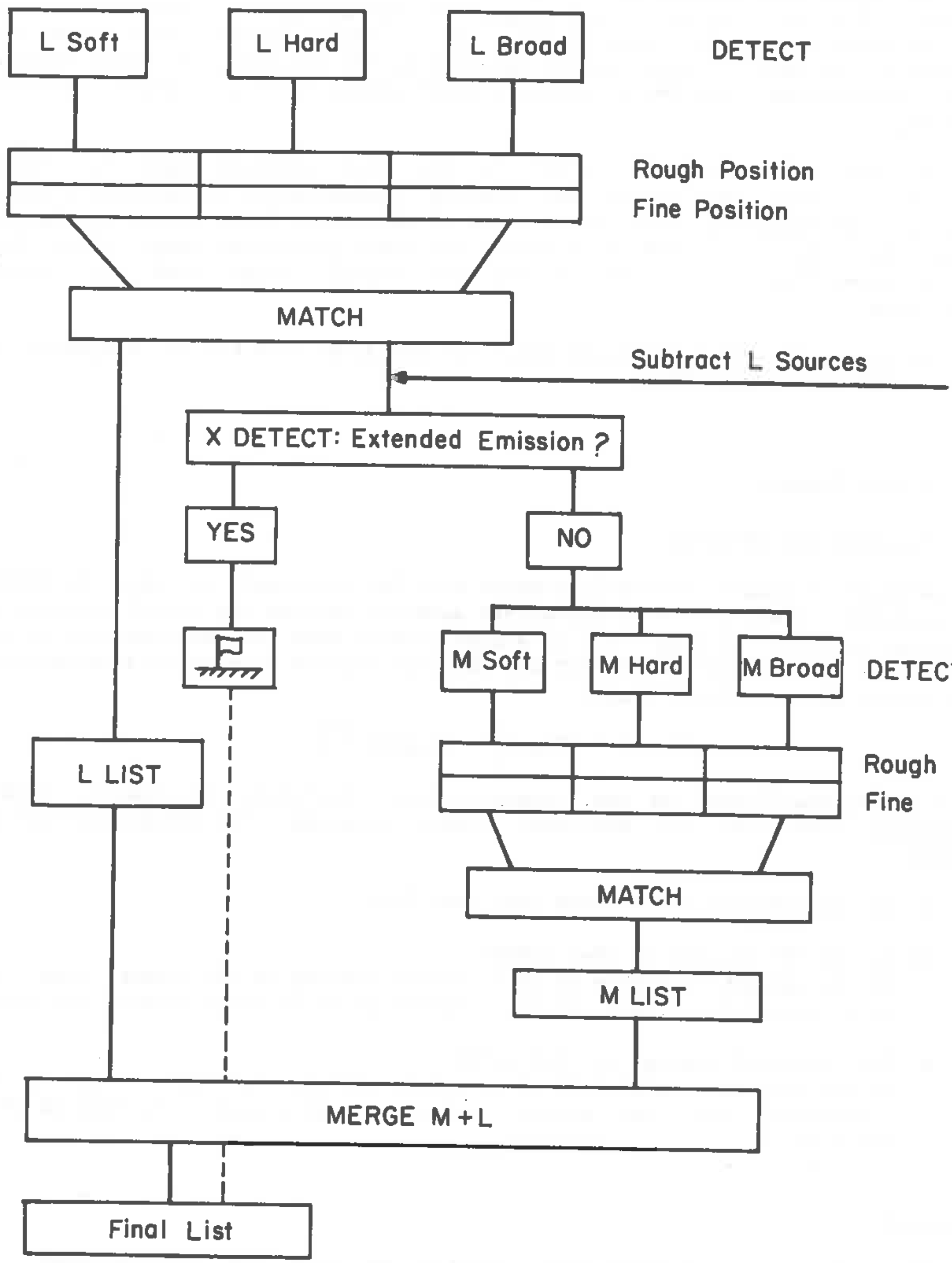
1) All MH sources are entered into the list.

2) For MB,MS sources in that order:
   If the source is within DS of a source already in the final list, it is considered the same source. Otherwise it is entered into the list.

3) For LH,LB,LS sources in that order:
   If the source is within DS of a source already in the list, it is considered the same source. Otherwise the L source is entered into the list.

Positions

The best source positions will usually be from the MDETECT/HARD: M because the original estimate should not be confused by nearby sources; HARD because the PRF is smaller (arrival positions for larger pulse heights are



L Soft
L Hard
L Broad
DETECT
Rough Position
Fine Position
MATCH
Subtract L Sources
X DETECT: Extended Emission ?
YES
NO
M Soft
M Hard
M Broad
DETECT
Rough
Fine
MATCH
M LIST
L LIST
MERGE M + L
Final List

Figure 5.2

more accurately known).

The position is determined by a Maximum Likelihood method (Memo of F. R. Harden, Jr., 19 May '78, attached to IPC SPECS). There is a significant systematic position error which is known to originate in the algorithm used to correct for detector nonlinearity ("DCOR"). The DCOR uncertainties are listed in Table 5.2.

Table 5.2 DCOR Systematic Uncertainties

PH Channels	1σ R<5'	1σ R>5'	90% Confidence R<5'	90% Confidence R>5'
1-3	36"	30"	77	64
4-10	12"	20"	26	43
1-10	14"	19"	30	41

The positional uncertainty listed for each source in the Source Summary Table is = $(30^2 + S^2)^{\frac{1}{2}}$ arc sec, where S = 90% statistical error in determining the centroid. The global value of 30" for the systematic contribution is used because the "correct" value depends on the source position, on which PI band was used for the position, and on the IPC gain (which PH channels). When PCOD (see "Miscellaneous" columns) indicates a SOFT origin for the position, the systematic error should be roughly twice that actually used (30"). Similarly, you may wish to increase the systematic contribution for R>5' (also listed under "Miscellaneous").

The "L" and "B" in the fourth line for the position of each source indicate galactic coordinates.

Source Intensity

Once the best position has been found, the source counts are determined for each PI band (with the appropriate sized standard box) by summing counts in the box(es) centered on the final position. The errors on the cell background are negligible for MDETECT because the background comes from long exposures. To obtain the final counting rate, we subtract the background, divide by the LIVE TIME, and multiply by the following three corrections.

CVIG, the vignetting correction compensates for the loss of mirror reflection efficiency off-axis. For REV1 processing, pre-flight calibration data at 1.5 keV have been fit with the following expressions:

VIGN = (-0.0003125*ANG - 0.00825)*ANG + 0.997 (ANG LTE 12')

and

VIGN = 1.1049 - 0.02136*ANG (ANG GT 12')

where ANG is off-axis distance in arcmin and CVIG = 1/VIGN. For spectral analysis (Sec. 5.10) the energy dependence of the vignetting is taken into account.

CMS is the scattering correction to compensate for counts scattered outside the standard box by small scale surface imperfections in the mirror. Since the importance of these imperfections increases with decreasing wavelength, a larger fraction of high energy photons are scattered than low energy photons. Values used were determined from pre-flight data: Carbon (.28 keV) for the SOFT correction and Al (1.5 keV) for HARD and BROAD.

CPRF compensates for the detector's limited ability to label photons with their correct coordinates. Although photons producing larger pulses are located more accurately than smaller pulses, the sizes of the DETECT boxes have been chosen to compensate for this effect and keep CPRF constant.

The errors on the final count rate and flux are approximate 68% confidence intervals (but the User should keep in mind the fact that Einstein IPC flux measurements are subject to a systematic uncertainty of ~10%).

WARNING: The quoted errors for the count rate and flux may be substantially underestimated for LDETECT in the case of weak or extended sources! See Sec. 5.3 below.

The conversion to flux involves the stated assumptions about the spectral distribution of the arriving photons. The equation for the power law is:

$$I(E) = k(1)\exp(-\sigma E * N_H) * E^{-n} \text{ photons cm}^{-2}\text{s}^{-1}\text{ keV}^{-1}$$

The Raymond Thermal spectrum is similar to that described in his article: Ap.J. Suppl. 35, 419, 1977.

Miscellaneous

The last two columns summarize results of analysis on succeeding pages and also list auxiliary data. "TFC" for "too few counts" is returned for VARY (secular), total cts < 50; VARY (periodic), total cts < 30; or EXTENT, counts within extent circle and annulus < 30. The "NA" (not analyzed) message is returned for VARY when processing has encountered an unrecoverable error.

"PSNO" stands for Probability Source Not zero, (i.e. referring to the intensity) and is provided as a guide to be used (cautiously) in assessing source existence. PSNO is the probability that a chi-squared distributed statistic will increase from its minimum value by the same amount that the MLM algorithm statistic increases when the source-strength parameter is decreased from the best-estimate value to zero. (May 19, 1978 Memo by F. R. Harnden, Jr.).

The estimate of source size ("EX") assumes a Gaussian distribution for source brightness and thus should be most useful to distinguish unresolved sources from slightly resolved sources (diameters of 1.5′ to 3′). For more extended sources, this estimate will probably deviate significantly from the actual source size unless the actual source brightness distribution is close to Gaussian.

Since the PRF is accurately known as a function of pulse height (PH), the extent analysis is done twice: once for low PH and once for high PH. The scheme simply compares the observed ratio of counts in a circle to counts in an annulus with the expected (PRF) ratio. The parameters are PH (low), PH channels 2-4, inner radius = 1.7′ outer radius 3.3′; PH (high), channels 5-9, inner radius = 1.0′, outer radius = 2.0′.

Details of the algorithm may be found in IPC SPECS Sec. 3.6.1.2.4 and Figs 3.6.1.7 and 3.6.1.11. The result of the high PH analysis is printed on the summary page.

The Hardness Ratio is a spectral indicator, HR = [PI(HARD) - PI(SOFT)]/PI(BROAD), where PI = ct in the standard circle (r = 3′) minus the normalized background as measured in a 5′ to 6′ annulus. The quoted error comes from Poisson statistics (IPC SPECS Sec. 3.6.1.2.1.2).

"RECO" indicates how many DETECT subcells are shadowed by the ribs (4′ wide). Details may be found in the IPC specs.

5.3 Local DETECT

The concept of a detect cell sliding (or jerking) across an image is described in the header of the LDETECT output. The side of the detect cells, d, for the 3 PI bands are listed on the field summary page. These values are 18 pixels for HARD and BROAD and 30 pixels for SOFT. These cells are divided into 9 subcells of dimension s = d/3 pixels.

The non-zero portion of the image is a 450 x 450 pixel array (rotated about the center by the roll angle) imbedded in a 1024 x 1024 pixel array with (0,0) in the upper left hand corner (North East). The field center is at (511.5, 511.5).

Position of Detect Cells

The initial position of the center of the LDETECT cell is at $Y_1 = 2.5s + 0.5$, $Z_1 = 0.5s + 0.5$. Successive positions move West (increasing Y) with steps of s (e.g. $Y_2 = Y_1 + s$, etc.). When the "line" is finished ($Y \simeq 1023$), the next line commences with center at Y_1, Z_2, where $Z_2 = Z_1 + s$.

The general expressions which will allow you to redetermine where the original detect cells were located are thus:

$$Y_i = (2.5s + 0.5) + ms,$$
$$Z_i = (0.5s + 0.5) + ns,$$

where n and m take on values of 0, 1, 2, . . .

Evaluation

Bearing in mind the "window" (i.e. 3 x 3 subcell detect box) and the "frame," (i.e. the 16 subcells surrounding the window) we understand that LDETECT is optimized for detection of point-like sources, i.e. those whose spatial (count) distribution closely conforms to that of the PRF (approximate Gaussian). In fact, this specialization is sharpened by the algorithm which separates source counts from background counts on the basis of the observed counts in the window and in the window plus frame. The only method to achieve this separation without using a global background (as in MDETECT) is to make assumptions about the distribution of source counts and background counts within the frame and window. Because LDETECT assumes an unresolved source (i.e. the PRF) and a uniform background, bizarre results can be obtained whenever a distribution for a source candidate deviates significantly from the PRF. Details of the algorithm are given in the IPC SPECS (Sec. 3.6.1.1), but here we excerpt the expressions for S and B when RECO=0:

$S = 1.912*C - 0.688*T$ (Total counts attributed to the source)

$B = 0.608*T - 0.688*C$ (Total counts attributed to background, normalized to the area of the DETECT cell: "cell BKG" on the L page.)

where C = total counts in the window ("cells CNTS" on printout).
T = total counts in the window and frame (not displayed on the printout).

Consider an extended source: the background will be much greater than the field average (as measured in the 8′ to 15′ annulus), and the source will have a lower intensity than a similar number of counts in a window with a frame having a normal background.

On the other hand, real sources close to threshold and spurious sources (a spatial enhancement caused by statistical fluctuations) will often display a distribution which is more strongly peaked than the PRF (statistical fluctuations with scale sizes greater than the PRF are selectively rejected by LDETECT just as extended sources are attenuated). Peaked distributions fool LDETECT into thinking that many background photons are actually source photons: the source intensity is artificially enhanced with an anomalously low background. For these reasons, LDETECT source intensities are subject to systematic uncertainties.

Signal to Noise and Threshold

The field background listed for each PI band is the average value found in the 8′to 15′ annulus. Based on simulations, a signal to noise threshold is then chosen to yield (on average) 1/3 spurious source per field per energy band. (This depends on the number of DETECT cells per field). Each source detection will have its local value of background with its corresponding threshold counts (greater or less than the global value) necessary to yield a local S/N equal to the global S/N threshold. The crux of the LDETECT algorithm is the use of a fixed threshold of S/N as opposed to a threshold of counts. This is the reason that S/N and threshold are listed for each source as well as for the field.

Matching

In order not to miss weak sources which fall near the edge of DETECT cells, a reduced S/N threshold is employed, and whenever the sliding DETECT cell satisfies this criterion, it sets a flag in a bitmap of the image field. Contiguous or overlapping flagged cells are then considered to be a candidate source. After an accurate position for each candidate source has been determined and tested against the original S/N threshold, all redundant detections within each band and among the 3 PI bands are matched to form a final L list.

5.4 Map DETECT

MDETECT employs a sliding DETECT cell, but relies on a background map to estimate the local background for the IPC. MDETECT is not run if a bright (>.6 ct s^{-1}) source is present in any band, if extended emission is definitely present in more than one band, or if extended emission is definitely present in one band and possibly present in one or more bands (see Sec. 5.1).

Construction of the Background Map

The background map is a linear combination of two reference maps. The first, "DSMAP," is constructed from the "Deep Survey" (long exposures on fields free of strong sources). The second (BEMAP) comes from data taken on the bright Earth.

After subtraction of the counting rate for sources found by LDETECT, the total field counting rate will be compared to that of the DSMAP, which has been scaled to the live time of the observation. If the target field rate is different from that of the DSMAP, then a contribution from the BEMAP will be added to (or subtracted from) the scaled DSMAP to produce the background map. That is, enough BE counts (field-distributed) will be added to, or subtracted from, the scaled DSMAP to equalize the overall count rate of the target map (source-subtracted) and the newly constructed background map.

S/N and Threshold

Since we now have a known background level which varies with location, we again employ a S/N Threshold rather than a "count threshold." The S/N threshold is found by simulations to be that S/N threshold which produces 1 spurious source per field for the background map (with its non-constant background level).

The local signal to noise,

$$S/N = (C - M)/\mathrm{SQRT}(C),$$

where C = counts in the DETECT cell ("cell cts" in the PRD output), and M = counts in the background map ("cell BKG").

Analysis then proceeds in a manner described for LDETECT. MDETECT is superior to LDETECT in that the background level is more accurately known AND in that the assumptions about source structure are relaxed (although the scattering correction still assumes a PRF distribution). For comparison see "Evaluation" of Section 5.3, LOCAL DETECT. The measured intensity will, however, still be limited to the detect cell, and thus is of little use for extended sources.

NB: MDETECT makes no corrections for rib shadows. Source intensities may be underestimated if RECO is greater than zero.

<u>Sensitivity Limit Tables</u>

Many investigators would like to have an accurate estimate concerning the ability of a particular exposure to detect sources. Since the background varies across the field, and vignetting, rib shadowing, spectral response, etc., also affect the counts received from a source, this is a non-trivial question. However, the "local" answer to the question is obtained every time the DETECT algorithm operates on a given location. When a source is detected, the information is caried to the appropriate output page (Secs. 5.3 and 5.4) and the results are also listed for the field center and for the positions of catalogued objects (Sec. 5.6). Although other locations must be examined off-line, a statistical summary is accumulated during DETECT.

Sensitivity Limit tables are given for each of the MDETECT runs and for minimum signal to noise ratios of 4 and 5. These tables are designed to respond to the following question:

Given a minimum S/N (e.g. 4) what is the frequency of occurrence for a background small enough that a source of intensity equal to or greater than SMIN will exceed the one sigma noise level by a factor of 4? Thus, in the SMIN tables, the distribution at small SMIN values will represent parts of the image with little vignetting and low background (i.e. optimal detection regions). Areas where source detection is "difficult" (field edges, high background, etc.) will contribute to the distribution for large SMIN.

Further details can be found in the IPC SPECS. Here we repeat only the equation from that document:

$$\mathrm{SMIN} = (\sigma^2 + \sigma(\sigma^2 + 4B)^{1/2})/2$$

where $\sigma = 4$ or 5 and B = the background in a detect cell, from the background map.

Corrections to the SMIN calculation include vignetting, mirror scattering, the PRF, and for the exposure time (i.e., ribs and edges).

5.5 Possible Identification List.

This page is self-explanatory.

5.6 Upper Limits for Catalogued Objects

For each position of a mini cat object which falls within the IPC field, (excluding the "possible identifications" listed on Page 5), we have calculated a 3σ upper limit for the X-ray counting rate and flux. Since the LDETECT (BROAD) algorithm is used, extended emission will bias the upper limits derived. Thus, the upper limits quoted refer only to unresolved structure: real structure with scales greater than ~3′ may be present at a level significantly higher than the quoted upper limit. This condition may exist if MDETECT was not run. Since all catalogued objects which fall within 3′ of a previously detected X-ray source will not be subjected to the 3σ upper limit calculation, MDETECT should already have located discrete, extended sources whose brightness is more than 3σ above background.

For the upper limit calculation, an LDETECT (BROAD) cell (detect window plus frame) is placed on the image at the position of the catalogued object. The details of obtaining the one sigma fluctuation level are given in IPC SPECS Sec. 3.6.1.1.1.1; and 3.6.2; the formula used for RECO = 0 is

$$ENET = (0.798*C + 0.369*T)^{1/2}$$

where C = counts in the window and T = counts in the frame and window. 3*ENET is then taken as the 3σ upper limit and after the usual corrections (Sec. 5.2 and 5.3) a count rate and flux in the broad band are calculated. This procedure will almost always result in a conservative 99% confidence interval, i.e., a more precise calculation employing a maximum likelihood technique with Poisson assumptions would yield a smaller upper limit.

5.7 Angular Size Data

Since the major contributor to the size of the PRF is the pulse height dependent electronic circuits of the IPC, critical tests for source extent are best performed in PH bands. To this end, we present radial distributions in two PH bands, where the net source counts within the standard 3′ radius circle are divided into 9 annuli plus the central circle, each radial bin adjusted to contain ~ 10% of the total net counts. For the low PH channels, the binning extends out to 5′.

5.8 Variability Output

Secular Test

In order to improve the S/N temporal analysis is performed only on data taken for good viewing geometry (VGSTAT≤2; Sec. 5.14). The "net cts" and "source counts" mentioned herein refer to counts received during this restricted time, and for all PI channels.

For sources with greater than 50 cts (source and background, in the standard circle), a chi-squared test for steady amplitude is applied. The number of timing bins is = source counts/25. Data gaps are not used and bins span across gaps. Degrees of freedom = bins - 1. The listed probability is that for obtaining the "observed" chi-squared (or greater) from random data.

<u>Periodic Test</u>

An FFT analysis (power spectrum) is performed on all sources with more than 30 counts (source and background) in the standard circle. Barycentric arrival times are used throughout. The Fourier component with the largest amplitude is printed out, together with the probability of obtaining that coefficient from a steady source. The Fourier analysis is normalized by a run on the background and thus there is a 1-1 correspondence between amplitude and probability.

5.9 Spectral Data.

This section is divided into two parts:

a) data binned according to PI bands for each source,

b) data binned according to PH bands.

a) PI Bands

The PI bins show the RAW and NET counts (3′ circle - normalized 5′ to 6′ annulus) in the 15 PI bins. The hardness ratio is described at the end of Sec. 5.2.

b) The PH Data

PH bins for the standard circle and background annulus are given.

5.10 Spectral Analysis of Sources

Any detected source within the centrally located 4′ x 4′ and with 200 or more net counts will be subjected to the following spectral analyses. These analyses operate on the basis of "CONSTANT ASPECT INTERVALS" (CAI)--periods of time during which the jitter in pointing is considered to be negligible insofar as its effect on displacing the source photons to locations on the IPC where the gain is different: i.e. jitter < 13" (see IPC SPECS Sec. 3.4.4).

After gain corrections have been applied to each CAI, the spectral fitting proceeds for: (1) a power law spectrum, (2) a thermal bremsstrahlung spectrum, and (3) a black body spectrum.

A "gradient-search" procedure is used to locate the chi-squared minimum, about which a grid of solutions for 5 values of the spectral parameter (index of power law or kT) and 5 values of the column density (N_H) is produced.

Chi-squared contour plots are also shown.

5.11 Contour Diagram

The contour diagram can be useful for representing the local surface brightness of an image and for judging the reality of features. To this end, a 256 x 256 array (PI BROAD) is constructed by collapsing (misnomered "ZOOM") 9 pixels to give 1 array element ("ZOOM 3"). Then a Gaussian function of FWHM = 64" is used for smoothing: NB: There is no background subtraction, and no vignetting corrections have been applied. The first contour is plotted at 2σ above the field background and subsequent levels (in terms of σ above background) are 4, 6, 8, 12, 16, 32, 64, 128 . . .

Most of the choices for parameters are subjective. We have chosen a Gaussian which will have little effect on the size of the final resolution, yet large enough to minimize statistical fluctuations on an element to element scale. Contour levels were chosen to be logarithmic to adequately represent large dynamic ranges. The extra contours at 6σ and 12σ were added to provide more detail for low level, resolved sources.

NB: The SIGMA adopted here is a global value computed from the field background level.

The field edges and positions of the rib shadows are shown. For observations containing segments with different roll angles, the rib positions are those from the first segment.

5.12 Sky Map and Mini Cats

A plot of objects within the IPC field is given, together with a print-out of the sources from mini-cats. See Chapter 8 for a description of the catalogues available on disk.

5.13 The Processed Data Log (Alias TGR File)

Detailed information about the time history of the observation are given in the next 3 sections. 5.13 is the processed data log; 5.14 presents strip charts of counting rates and status indicators; and 5.15 shows strip charts of aspect related quantities.

The time history is printed out to help you identify good data intervals and to understand why other intervals were rejected. The notes to the log are meant to make the table self-contained.

In some instances, you may wish to recover data rejected for various reasons. With REV1 processing, it is no longer necessary to reprocess the whole observation in order to retrieve HIBKGD intervals, masked out areas, etc.

5.14 Strip Charts: Count Rates and Status

The strip charts are arranged according to the HUTS which make up the observation. Seconds of time from the beginning of the HUT are shown along the top of the page. The actual labeling of seconds is rather indirect since all of the plotted data refer to major and minor frames (seconds are of secondary concern!). Since a major frame is equal to 40.96 secs, a "convenient" reference point in the two scales occurs at 12.5 Maj frames = 512 secs. Therefore the seconds line is labelled every 512 seconds (full ticks), each such interval being divided into 10 sections (half ticks) of 51.2 sec duration, and each of these sections further subdivided into 10 subintervals (tiny ticks) of 5.12 secs duration. Along the bottom of the page we have 10 major frames [full tick, labelled 1280 for minor frame count - (128 minor frames = 1 major frame)], subdivided into 10 single major frames (half-tick); and finally every major frame being divided into 8 parts (tiny ticks) of 16 minor frames each. Time zero for both scales can be found from the TGR list (Sec. 5.13); the start major frame of the plot (which can differ by ±1 from the HUT number) is listed in Section 1 of the output.

Count Rate Strips

Three count rates are shown at the top of the page and a further four are shown about mid-page. The labelled units are in c/s. The strips are double plotted: before the high sensitivity plot is driven off-scale, a low sensitivity plot becomes apparent. The labelled scale refers to the low sensitivity plot (divide the labels by ten for the high sensitivity).

The first three count rates are so-called "secondary science" channels (not subject to dead time).

TE = Total Events detected by the electronics

VE = Valid Events (approved for telemetry)

BK = the guard counter (Background) rate.

The "primary science" channels are subject to "dead time" caused by the maximum capacity of the telemetry at 125 ct/s:

PI SOFT, PI HARD, and PI REST show the count rates which make up the final image. The MASKED OUT rate shows the telemetered counts which were later found to be in the outer (masked) region of the field.

<u>STATUS STRIPS</u>

Nestled between the above mentioned sets of count rates, are four status indicators. BKSTAT and VGSTAT read <u>lower</u> for better data, whereas ASPECT and IMAGE read <u>higher</u> for better data.

<u>BKSTAT</u>: 0 = not computed

1	= low background rate	0-40c/s
2	= moderate background rate	40-50c/s
3	= high background rate	50-90c/s
4	= extremely high background rate	GT90c/s
5	= error	

These count rates are for the guard counter (particle background).

<u>VGSTAT</u> This delineates the status of the viewing geometry:

0 = not computed.
1 = best data
2 = better data
3 = good data
4 = bad data (routinely causes data rejection)
5 = unusable data (Earth blocked)
6 = error

The term "viewing geometry" indicates the interplay of the Sun/Earth/Satellite angle (<u>SSANG</u>) and the Earth/Satellite/Target angle (<u>EPANG</u>). These two angles are plotted below the PI rate traces. For example, the worst condition which still allows data usage would be SSANG $< 90^{\circ}$ (i.e. satellite on the day side of the Earth) and EPANG in the range 86°–120° (line of sight close to the horizon). Details are given in IPC SPECS (Figs. 3.2.1 and 3.2.2).

<u>ASPECT</u> allows a quick indication of what class of solution was available (see Chapter 3).

0 = not computed
1 = no solution
2 = extrapolated
3 = map mode
4 = locked on to guide stars

5 = error

<u>IMAGE</u> shows when your image is accumulating counts
0 = not computed
1 = all data rejected
2 = some rejected, some accepted
3 = all data accepted
4 = error

Further down the page we find SSANG and EPANG (described above); BODS for "Bright Object Detectors" (namely the Earth, once the moon); and SAADS for South Atlantic Anomaly Detectors (these are two Geiger counters which count energetic, charged particles).

5.15 STRIP CHARTS: ASPECT

General considerations concerning aspect are discussed in Chapter 3.

For the aspect strips, the Major Frame time line is at the top and the seconds are at the bottom. The first two traces show the U and V (cartesian) coordinates of STAR TRACKER A and strips 5 and 6 give the same quantities for STAR TRACKER C. Strip 3 shows the separation of the two guide stars (a constant value indicating "locked" mode).

The bottom three traces show the gyro monitors: deviations from a straight line indicating momentum transfer from gyro to spacecraft.

5.16 Merge Log

A log created during processing details the processing system configuration and data files used in the reduction. The version printed here with the PRD output will be a short version. The full log will be available on microfiche at CFA. In any event, most users will not need this information.

5.17 Conversion of Count Rate to Flux

In section 5.2 observed fluxes were given for each source for a fixed set of assumed spectral parameters described in the notes under the table. Since it is often desirable to estimate fluxes for other spectral distributions, a set of figures have been prepared which give the Energy Conversion Factor (ECF) as a function of the column density (N_H) and the primary spectral parameter α (photon number index) or kT.

To obtain a flux estimate, find ECF from the appropriate figure and obtain the flux by

$$F = CCS(BROAD)*ECF \text{ erg cm}^{-2} \text{ s}^{-1}$$

where CCS(BROAD) = corrected count s^{-1} from the source summary page (or elsewhere) in the BROAD band.

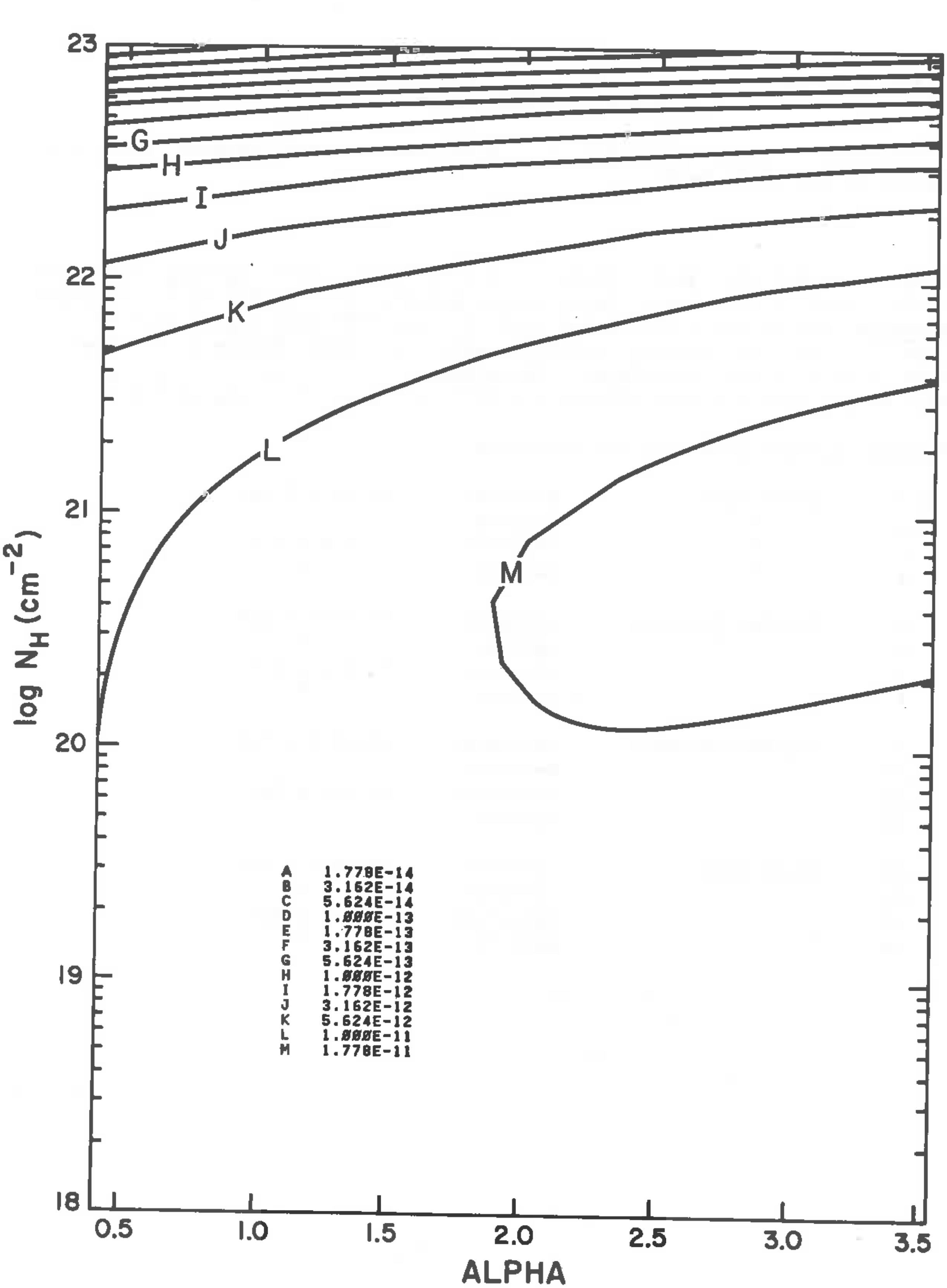
Example

Suppose we believe that Source X has a very soft thermal spectrum (kT = 0.8) with a relatively large column density of 3×10^{22} cm^{-2}. To find the observed flux in the 0.2-4.0 keV band, we find EPC from Figure 5A.7 to be 4.4×10^{-11}. On the source summary table we find Source X to have a "Rate*E3" = 29.6 in the broad band. Therefore,

Flux (0.2-4 keV) = $(29.6/1000)*4.4 \times 10^{-11} = 1.3 \times 10^{-12}$ erg cm^{-2} s^{-1}

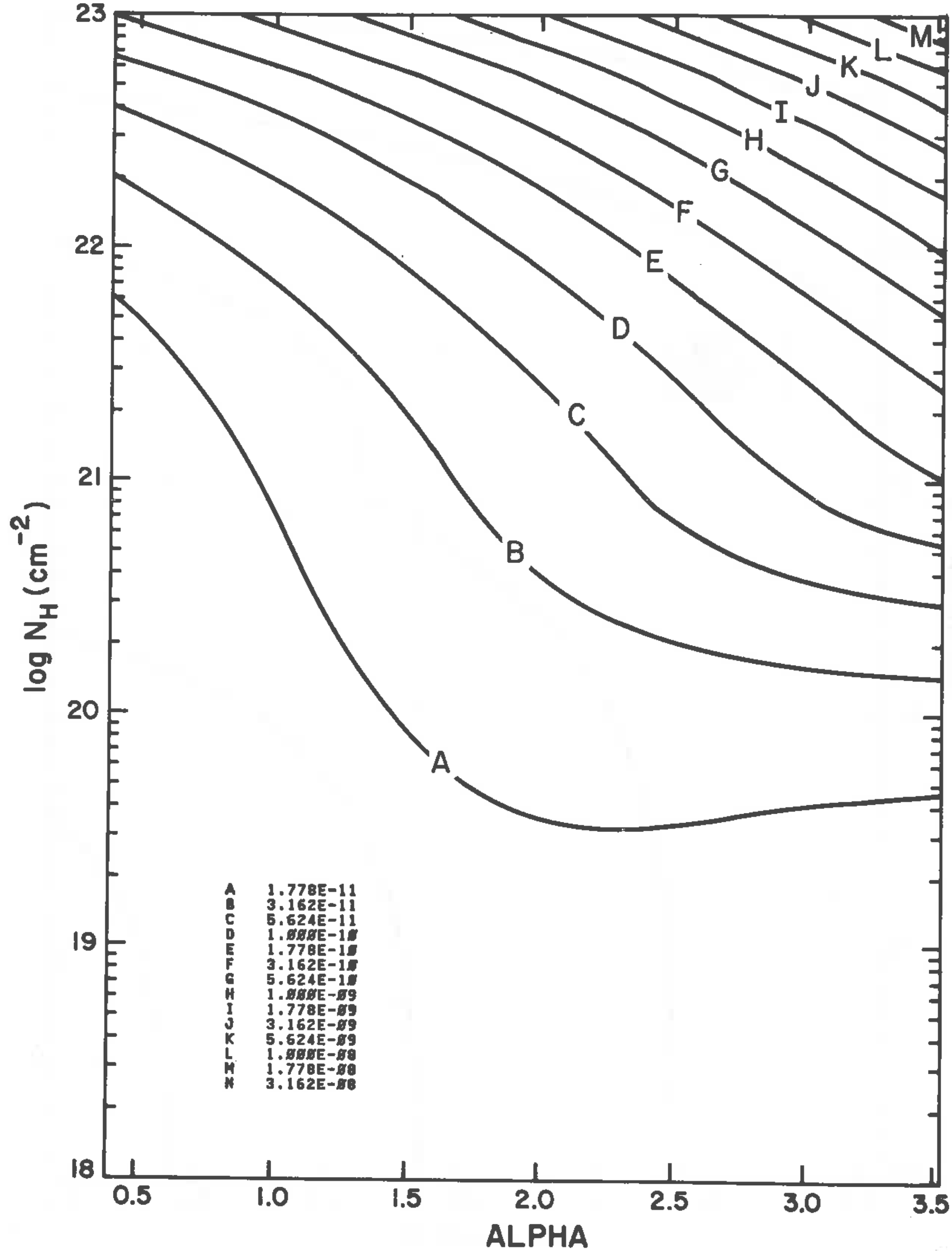
The figures included here are the following:

Fig. 5A.1	Power Law	observed	0.15-1.5 keV
.2	"	emitted	"
.3	"	observed	0.2-4.0 keV
.4	"	emitted	"
.5	Thermal Brems+G	observed	0.15-1.5 keV
.6	"	emitted	"
.7	"	observed	0.2-4.0 keV
.8	"	emitted	"
.9	Raymond Thermal	observed	0.15-1.5 keV
.10	"	emitted	"
.11	"	observed	0.2-4.0 keV
.12	"	emitted	"
.13	Black Body	observed	0.15-1.5 keV
.14	"	emitted	"
.15	"	observed	0.2-4.0 keV
.16	"	emitted	"



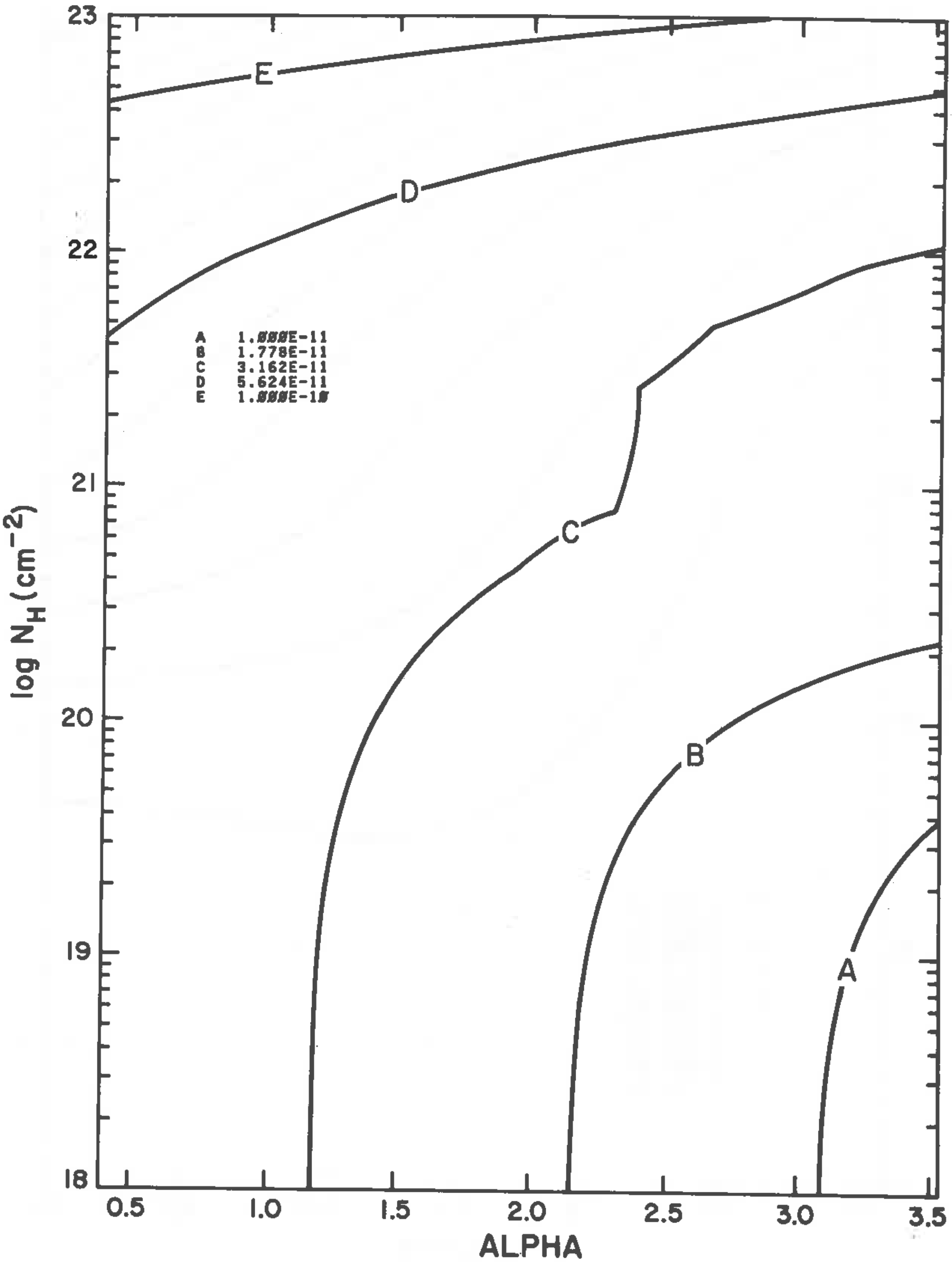
log N_H (cm^{-2})
23
22
21
20
19
18
0.5
1.0
1.5
2.0
2.5
3.0
3.5
ALPHA
G
H
I
J
K
L
M
A 1.778E-14
B 3.162E-14
C 5.624E-14
D 1.000E-13
E 1.778E-13
F 3.162E-13
G 5.624E-13
H 1.000E-12
I 1.778E-12
J 3.162E-12
K 5.624E-12
L 1.000E-11
M 1.778E-11

Figure 5A.1



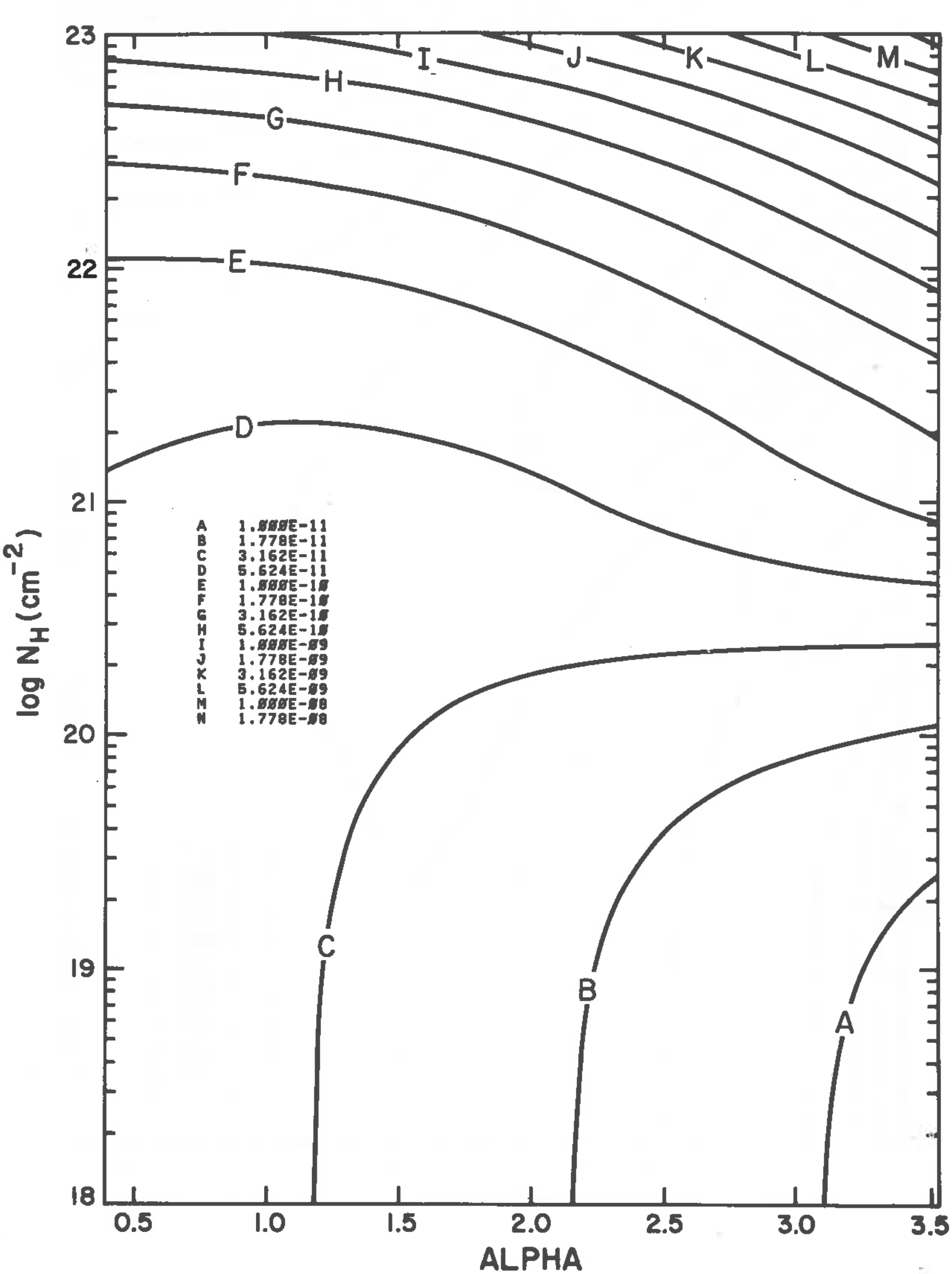
23
22
21
20
19
18
log N_H (cm^{-2})
0.5
1.0
1.5
2.0
2.5
3.0
3.5
ALPHA
A
B
C
D
E
F
G
H
I
J
K
L
M
A 1.778E-11
B 3.162E-11
C 5.624E-11
D 1.000E-10
E 1.778E-10
F 3.162E-10
G 5.624E-10
H 1.000E-09
I 1.778E-09
J 3.162E-09
K 5.624E-09
L 1.000E-08
M 1.778E-08
N 3.162E-08

Figure 5A.2



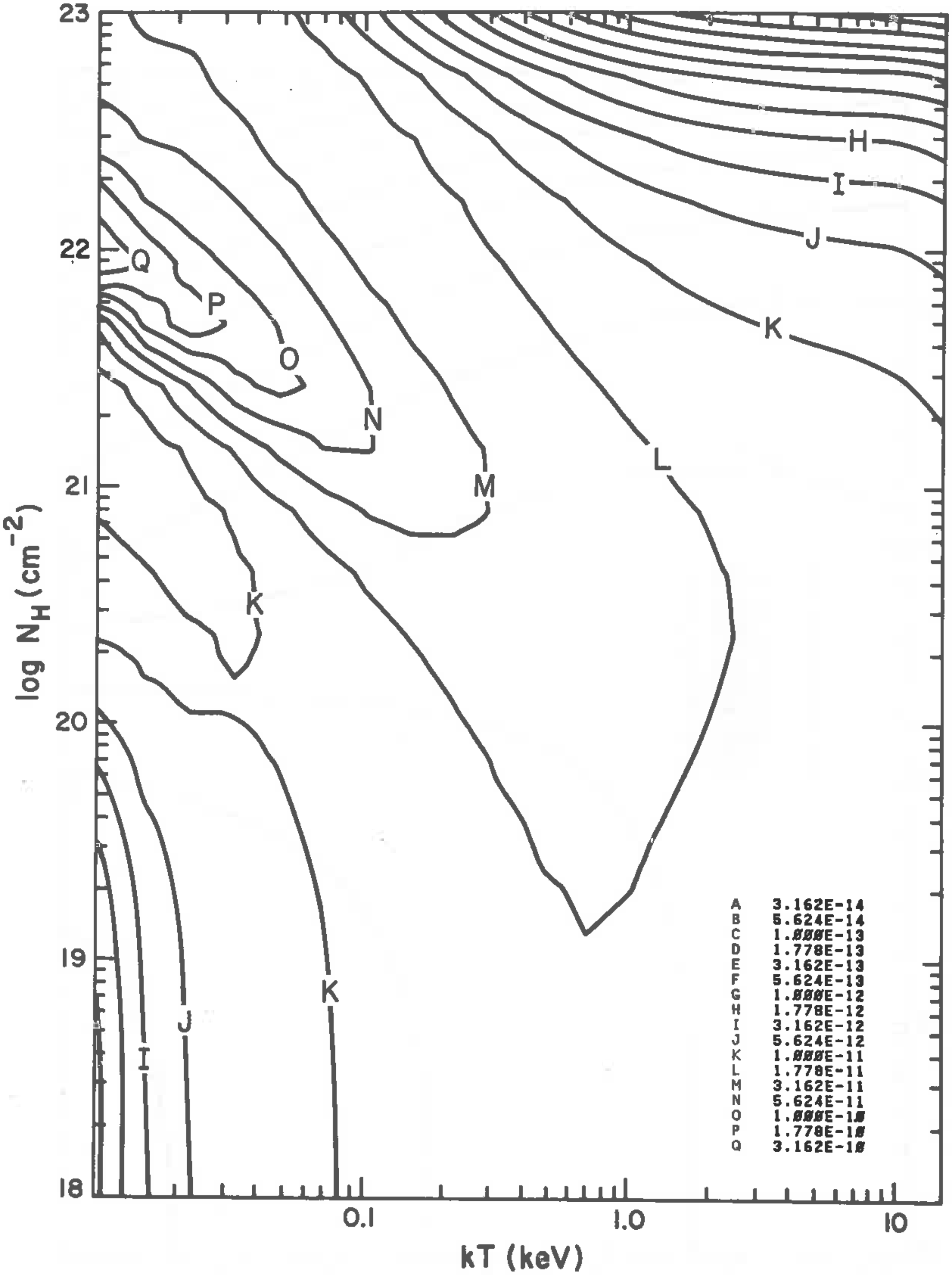
23
22
21
20
19
18
log N_H (cm^{-2})
0.5
1.0
1.5
2.0
2.5
3.0
3.5
ALPHA
A 1.000E-11
B 1.778E-11
C 3.162E-11
D 5.624E-11
E 1.000E-10
A
B
C
D
E

Figure 5A.3



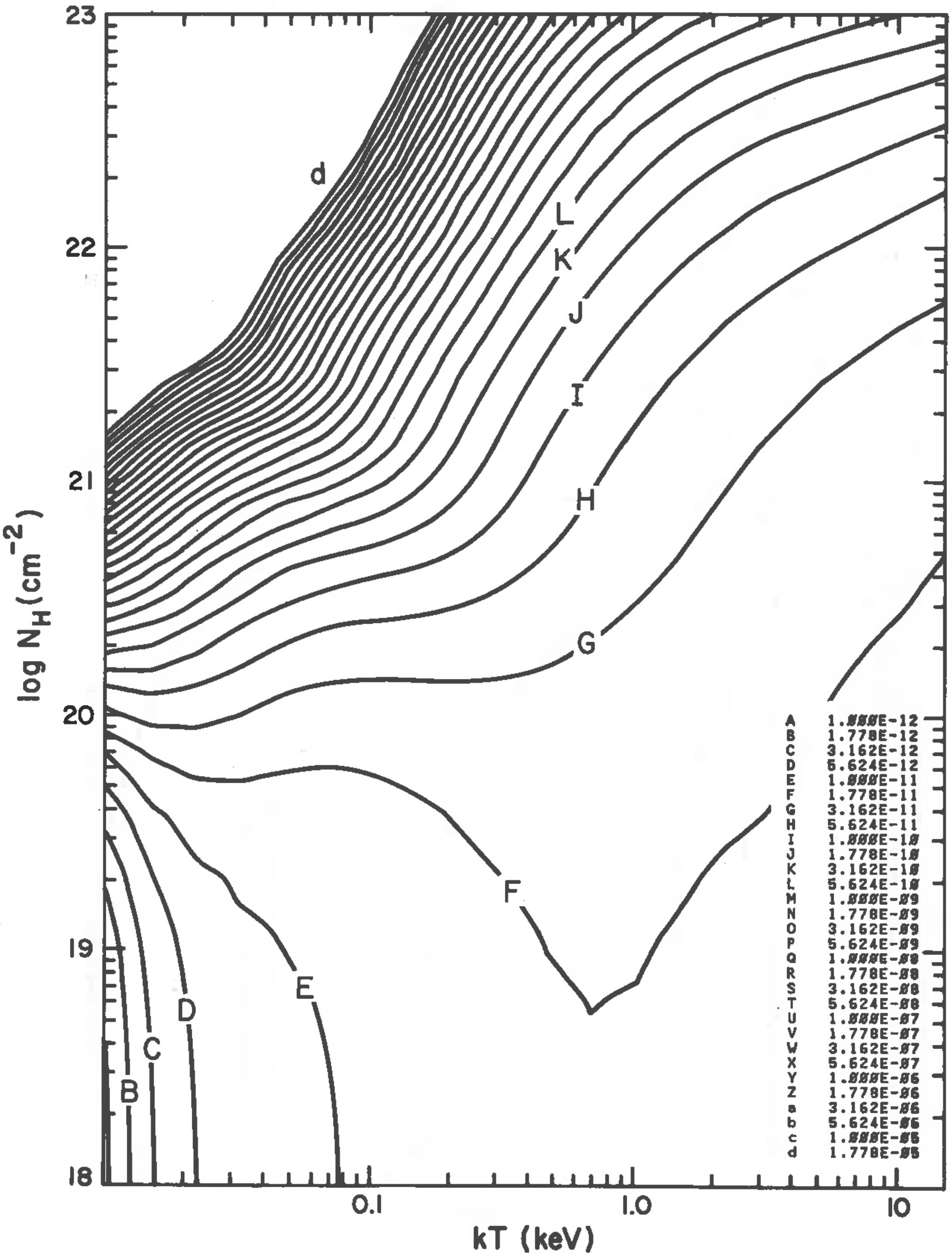
23
22
21
20
19
18
log N_H (cm^{-2})
0.5
1.0
1.5
2.0
2.5
3.0
3.5
ALPHA
A B C D E F G H I J K L M
A 1.ØØØE-11
B 1.778E-11
C 3.162E-11
D 5.624E-11
E 1.ØØØE-1Ø
F 1.778E-1Ø
G 3.162E-1Ø
H 5.624E-1Ø
I 1.ØØØE-Ø9
J 1.778E-Ø9
K 3.162E-Ø9
L 5.624E-Ø9
M 1.ØØØE-Ø8
N 1.778E-Ø8

Figure 5A.4



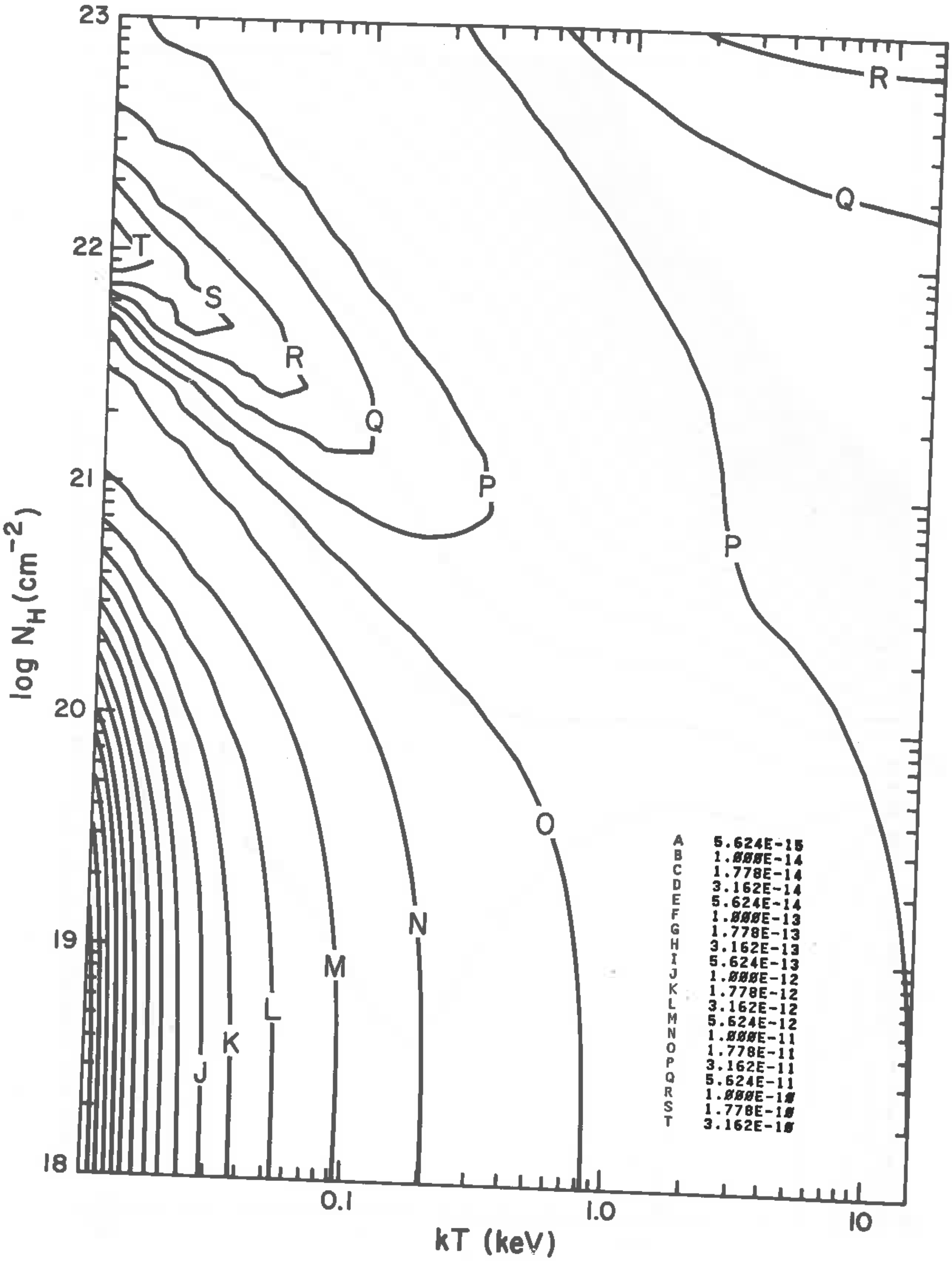
23
22
21
20
19
18
log N_H (cm^{-2})
0.1
1.0
10
kT (keV)
H
I
J
K
L
M
N
O
P
Q
K
K
J
I
A 3.162E-14
B 5.624E-14
C 1.000E-13
D 1.778E-13
E 3.162E-13
F 5.624E-13
G 1.000E-12
H 1.778E-12
I 3.162E-12
J 5.624E-12
K 1.000E-11
L 1.778E-11
M 3.162E-11
N 5.624E-11
O 1.000E-10
P 1.778E-10
Q 3.162E-10

Figure 5A.5



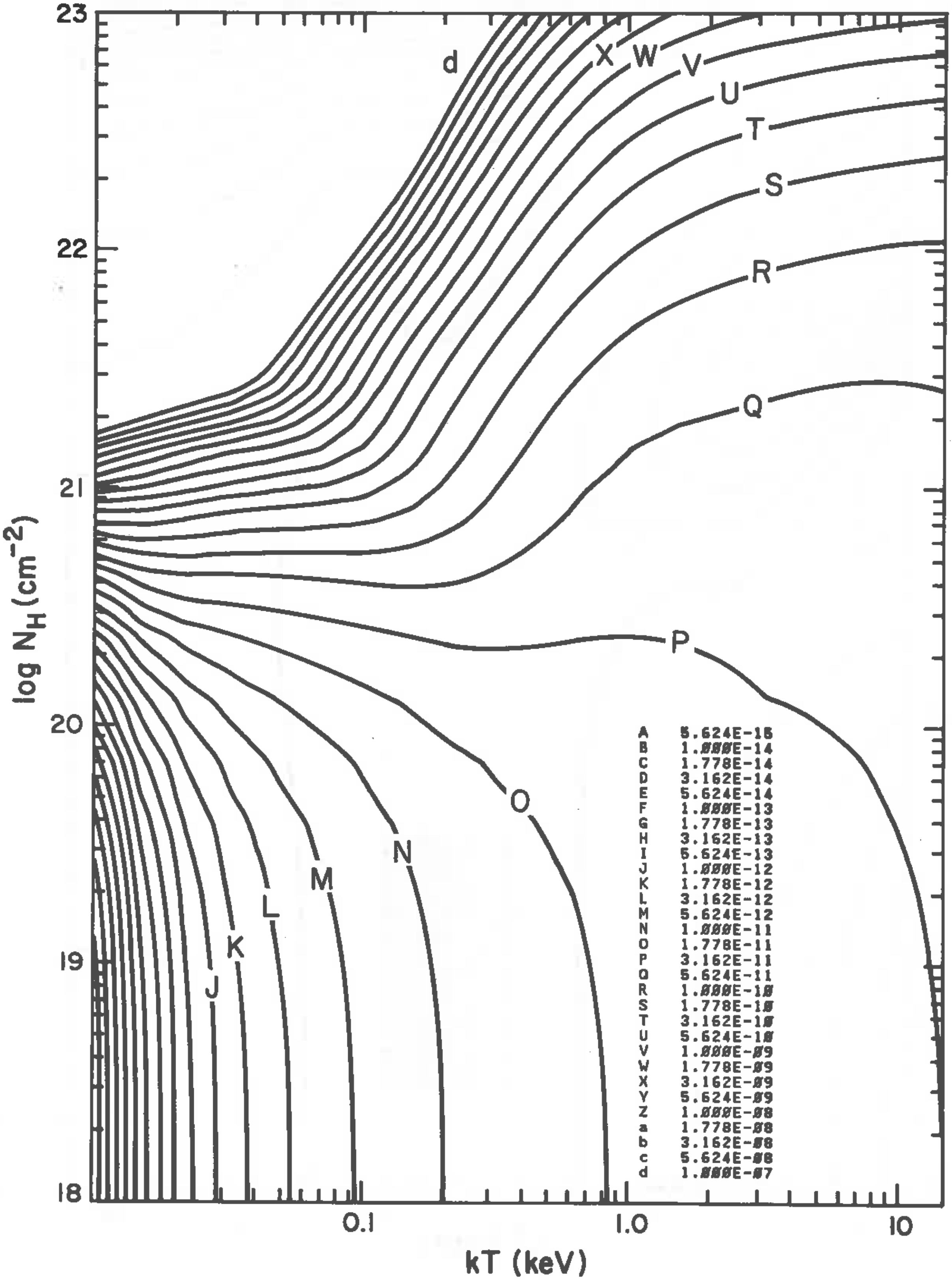
log N_H (cm^{-2})
kT (keV)
23
22
21
20
19
18
0.1
1.0
10
d
L
K
J
I
H
G
F
E
D
C
B
A 1.ØØØE-12
B 1.778E-12
C 3.162E-12
D 5.624E-12
E 1.ØØØE-11
F 1.778E-11
G 3.162E-11
H 5.624E-11
I 1.ØØØE-1Ø
J 1.778E-1Ø
K 3.162E-1Ø
L 5.624E-1Ø
M 1.ØØØE-Ø9
N 1.778E-Ø9
O 3.162E-Ø9
P 5.624E-Ø9
Q 1.ØØØE-Ø8
R 1.778E-Ø8
S 3.162E-Ø8
T 5.624E-Ø8
U 1.ØØØE-Ø7
V 1.778E-Ø7
W 3.162E-Ø7
X 5.624E-Ø7
Y 1.ØØØE-Ø6
Z 1.778E-Ø6
a 3.162E-Ø6
b 5.624E-Ø6
c 1.ØØØE-Ø5
d 1.778E-Ø5

Figure 5A.6



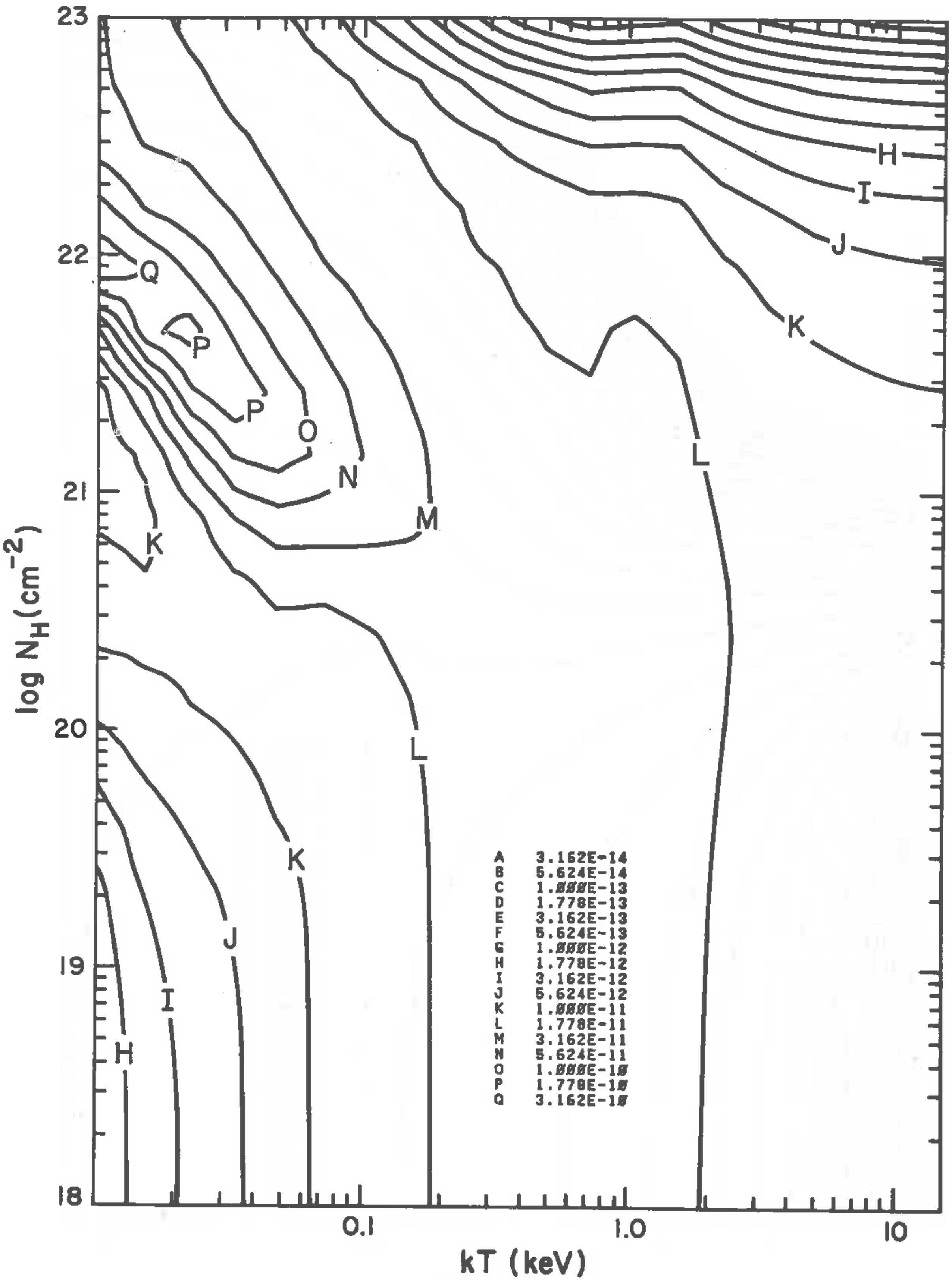
log N_H (cm^{-2})
23
22
21
20
19
18
0.1
1.0
10
kT (keV)
J
K
L
M
N
O
P
Q
R
S
T
A 5.624E-15
B 1.000E-14
C 1.778E-14
D 3.162E-14
E 5.624E-14
F 1.000E-13
G 1.778E-13
H 3.162E-13
I 5.624E-13
J 1.000E-12
K 1.778E-12
L 3.162E-12
M 5.624E-12
N 1.000E-11
O 1.778E-11
P 3.162E-11
Q 5.624E-11
R 1.000E-10
S 1.778E-10
T 3.162E-10

Figure 5A.7



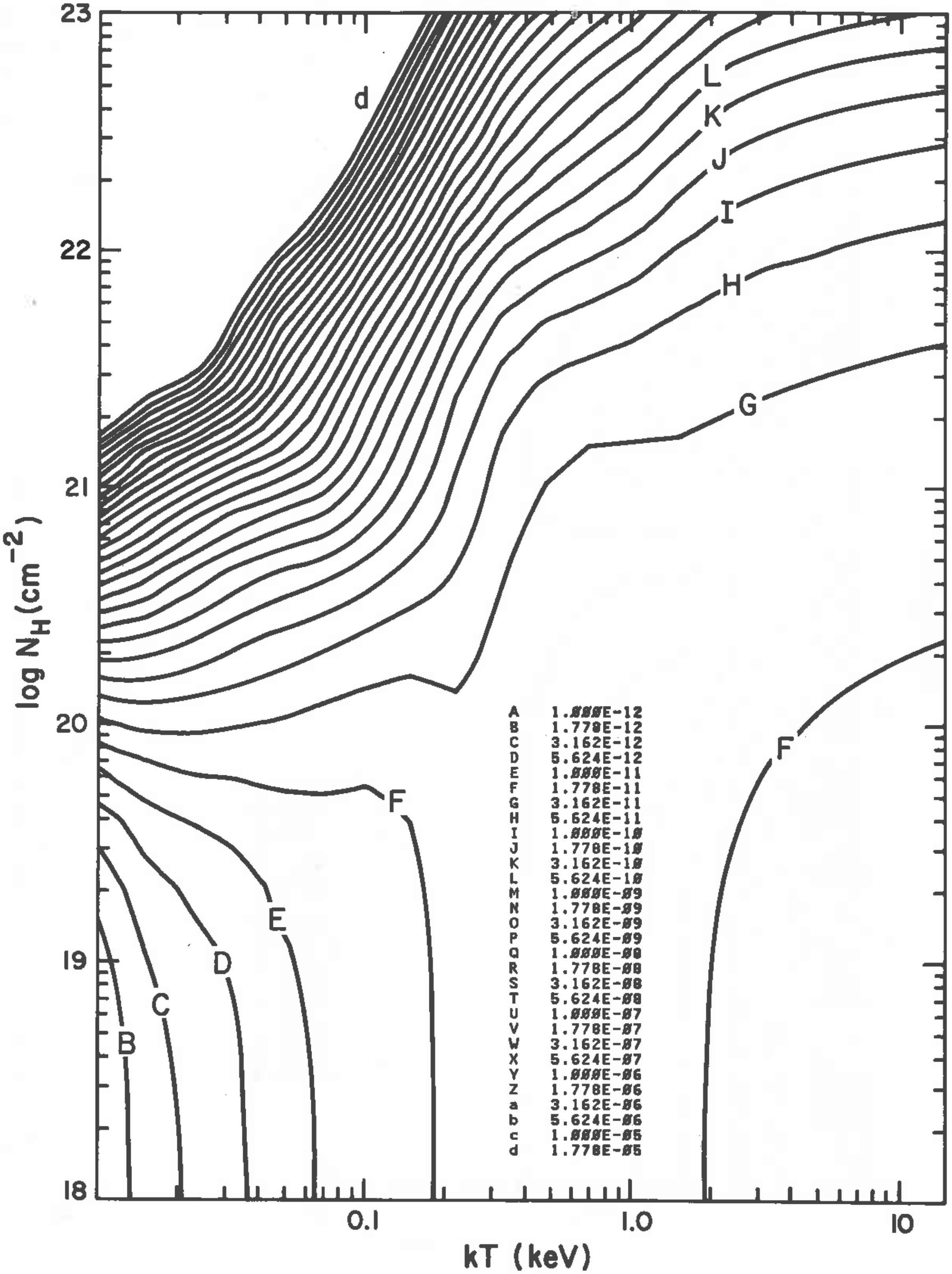
log N_H (cm^{-2})
23
22
21
20
19
18
kT (keV)
0.1
1.0
10
d
X
W
V
U
T
S
R
Q
P
O
N
M
L
K
J
A 5.624E-15
B 1.000E-14
C 1.778E-14
D 3.162E-14
E 5.624E-14
F 1.000E-13
G 1.778E-13
H 3.162E-13
I 5.624E-13
J 1.000E-12
K 1.778E-12
L 3.162E-12
M 5.624E-12
N 1.000E-11
O 1.778E-11
P 3.162E-11
Q 5.624E-11
R 1.000E-10
S 1.778E-10
T 3.162E-10
U 5.624E-10
V 1.000E-09
W 1.778E-09
X 3.162E-09
Y 5.624E-09
Z 1.000E-08
a 1.778E-08
b 3.162E-08
c 5.624E-08
d 1.000E-07

Figure 5A.8



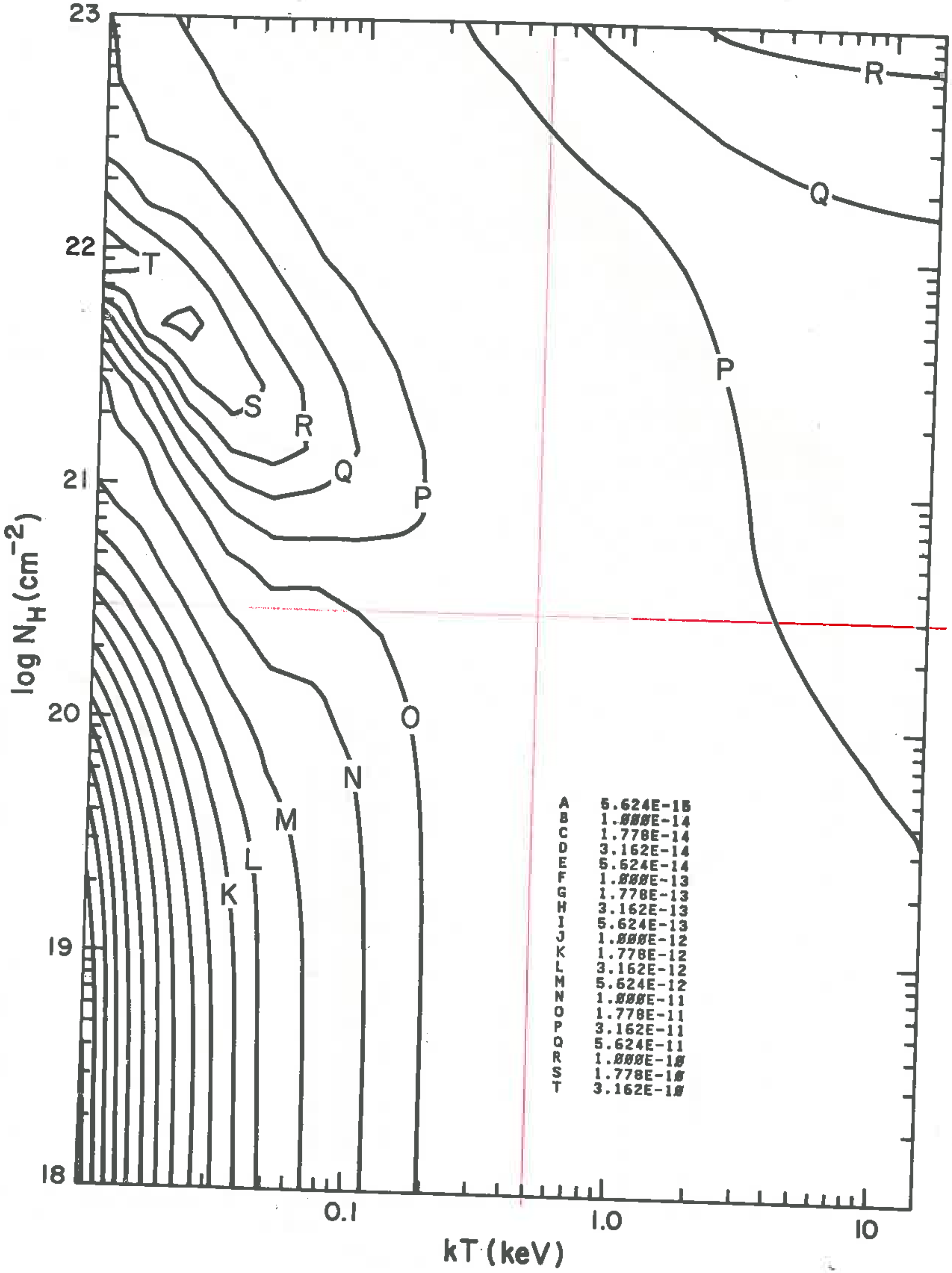
23
22
21
20
19
18
log $N_H (cm^{-2})$
0.1
1.0
10
kT (keV)
H
I
J
K
L
M
N
O
P
Q
A 3.162E-14
B 5.624E-14
C 1.000E-13
D 1.778E-13
E 3.162E-13
F 5.624E-13
G 1.000E-12
H 1.778E-12
I 3.162E-12
J 5.624E-12
K 1.000E-11
L 1.778E-11
M 3.162E-11
N 5.624E-11
O 1.000E-10
P 1.778E-10
Q 3.162E-10

Figure 5A.9



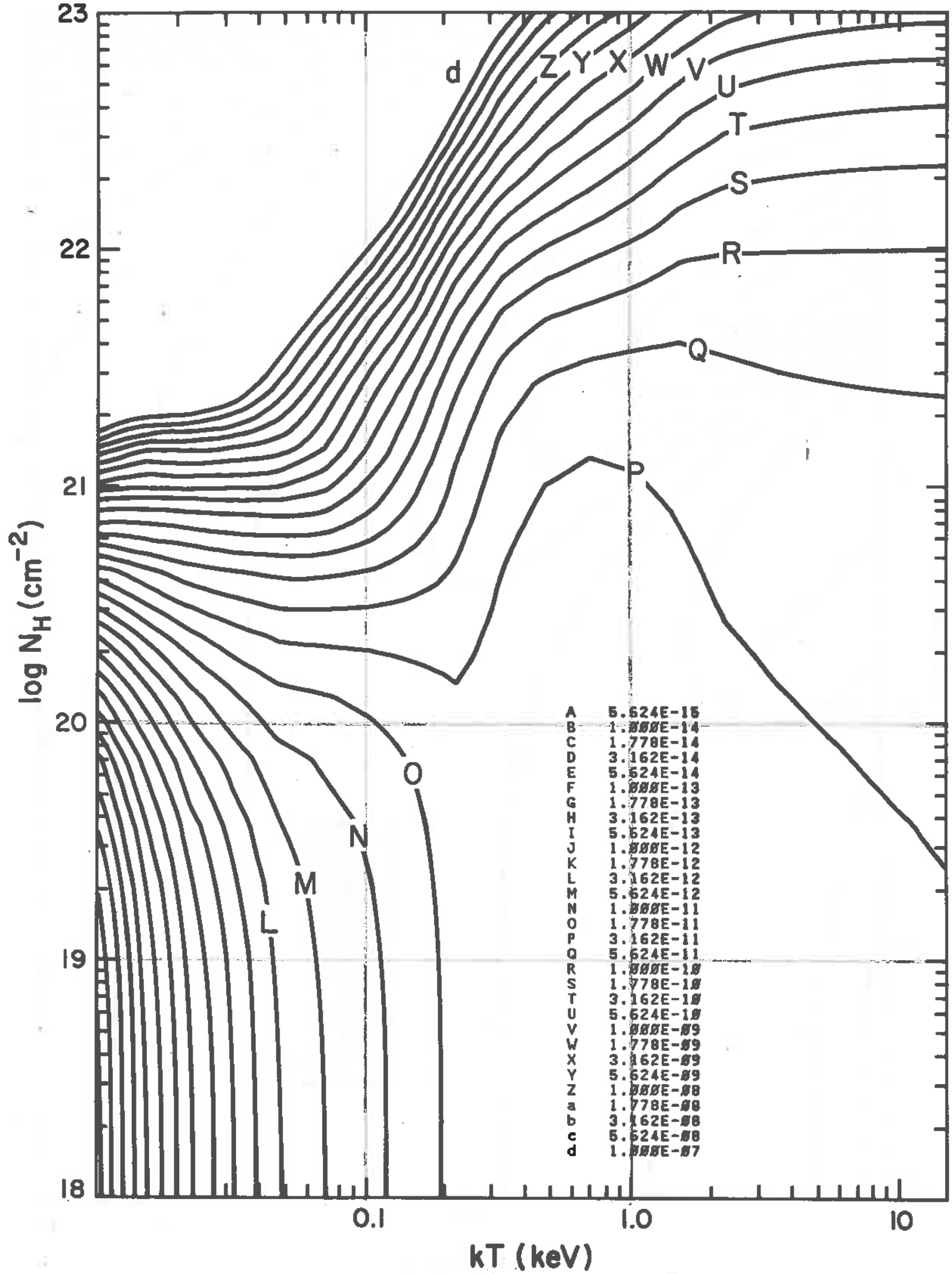
23
22
21
20
19
18
log N_H (cm^{-2})
0.1
1.0
10
kT (keV)
d
L
K
J
I
H
G
F
E
D
C
B
A 1.ØØØE-12
B 1.778E-12
C 3.162E-12
D 5.624E-12
E 1.ØØØE-11
F 1.778E-11
G 3.162E-11
H 5.624E-11
I 1.ØØØE-1Ø
J 1.778E-1Ø
K 3.162E-1Ø
L 5.624E-1Ø
M 1.ØØØE-Ø9
N 1.778E-Ø9
O 3.162E-Ø9
P 5.624E-Ø9
Q 1.ØØØE-Ø8
R 1.778E-Ø8
S 3.162E-Ø8
T 5.624E-Ø8
U 1.ØØØE-Ø7
V 1.778E-Ø7
W 3.162E-Ø7
X 5.624E-Ø7
Y 1.ØØØE-Ø6
Z 1.778E-Ø6
a 3.162E-Ø6
b 5.624E-Ø6
c 1.ØØØE-Ø5
d 1.778E-Ø5

Figure 5A.10



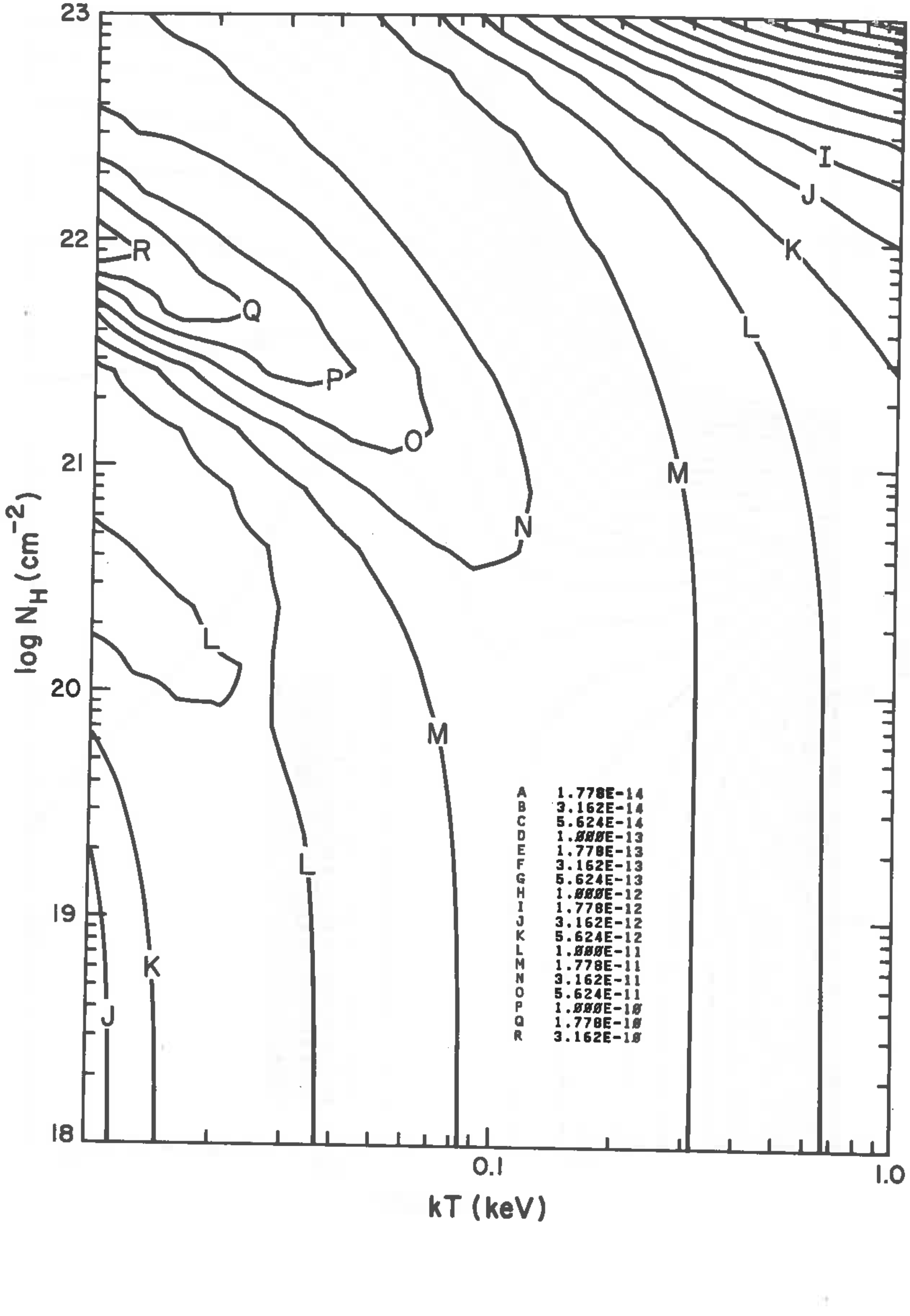
23
22
21
20
19
18
log N_H (cm^-2)
0.1
1.0
10
kT (keV)
T
S
R
Q
P
O
N
M
L
K
R
Q
P
A 5.624E-15
B 1.ØØØE-14
C 1.778E-14
D 3.162E-14
E 5.624E-14
F 1.ØØØE-13
G 1.778E-13
H 3.162E-13
I 5.624E-13
J 1.ØØØE-12
K 1.778E-12
L 3.162E-12
M 5.624E-12
N 1.ØØØE-11
O 1.778E-11
P 3.162E-11
Q 5.624E-11
R 1.ØØØE-1Ø
S 1.778E-1Ø
T 3.162E-1Ø

Figure 5A.11



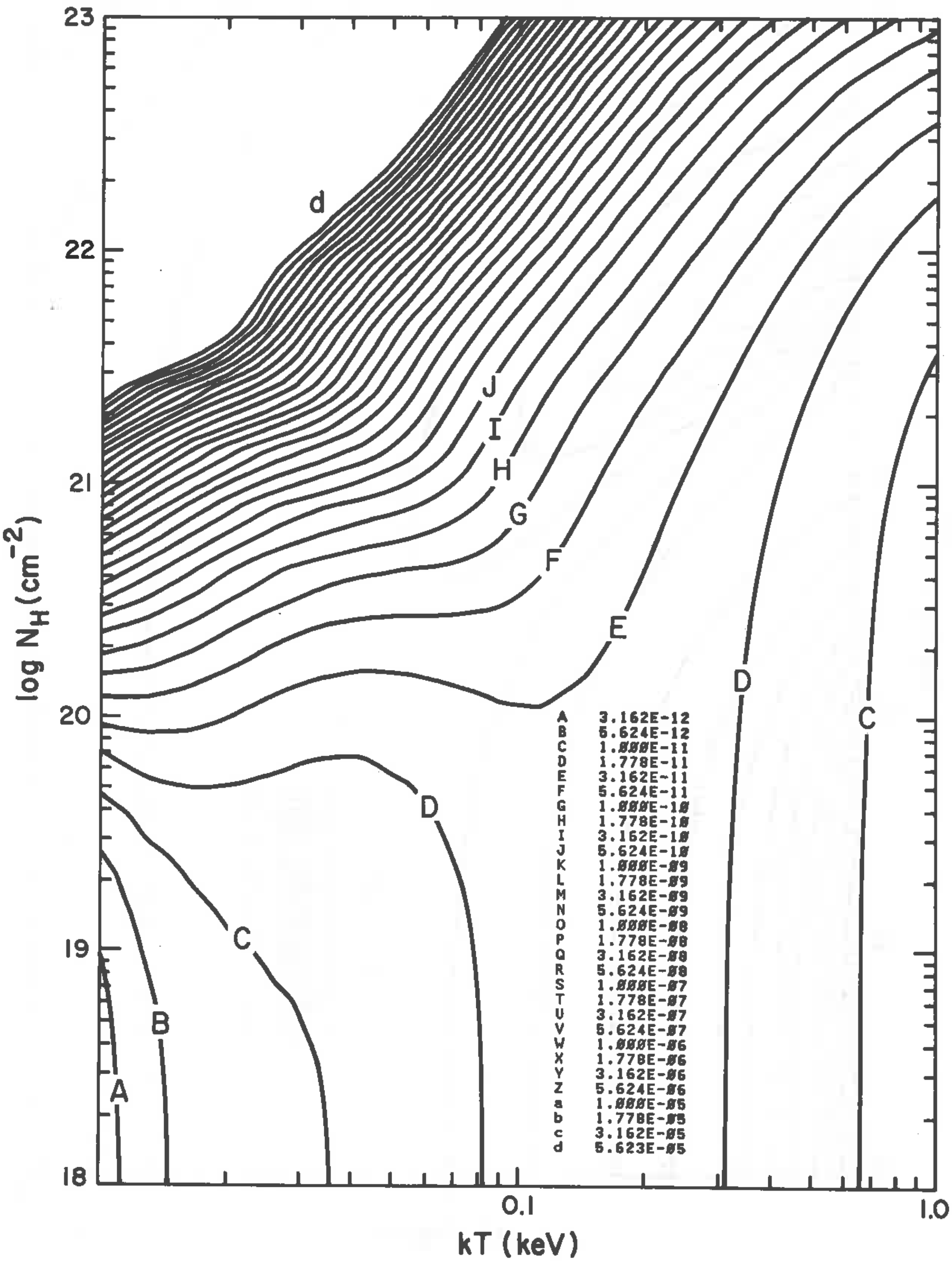
log N_H (cm^-2)
kT (keV)
23
22
21
20
19
18
0.1
1.0
10
d
Z Y X W V
U
T
S
R
Q
P
O
N
M
L
A 5.624E-15
B 1.000E-14
C 1.778E-14
D 3.162E-14
E 5.624E-14
F 1.000E-13
G 1.778E-13
H 3.162E-13
I 5.624E-13
J 1.000E-12
K 1.778E-12
L 3.162E-12
M 5.624E-12
N 1.000E-11
O 1.778E-11
P 3.162E-11
Q 5.624E-11
R 1.000E-10
S 1.778E-10
T 3.162E-10
U 5.624E-10
V 1.000E-09
W 1.778E-09
X 3.162E-09
Y 5.624E-09
Z 1.000E-08
a 1.778E-08
b 3.162E-08
c 5.624E-08
d 1.000E-07

Figure 5A.12



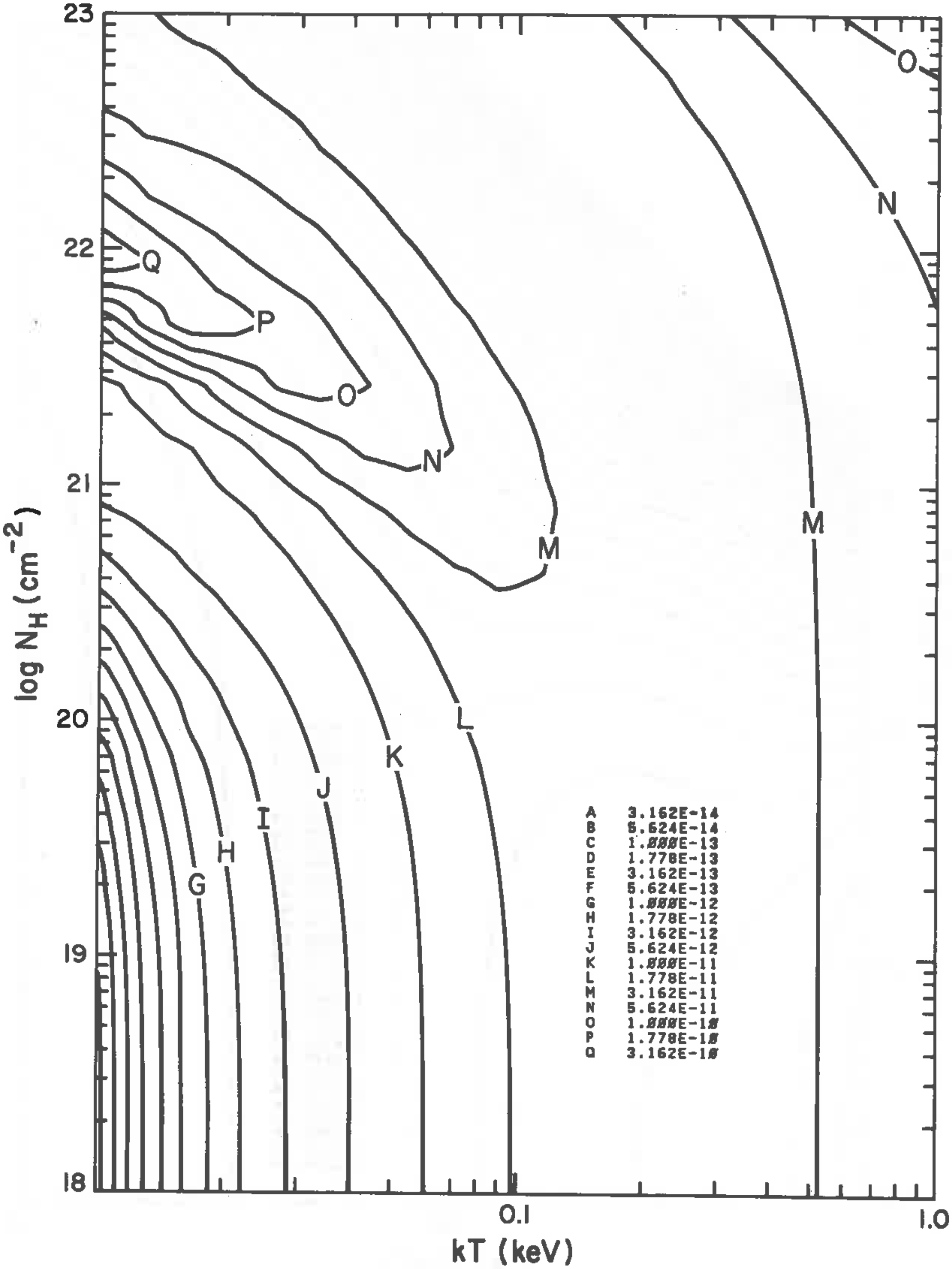
23
22
21
20
19
18
log N_H (cm^{-2})
0.1
1.0
kT (keV)
I
J
K
L
M
N
O
P
Q
R
A 1.778E-14
B 3.162E-14
C 5.624E-14
D 1.000E-13
E 1.778E-13
F 3.162E-13
G 5.624E-13
H 1.000E-12
I 1.778E-12
J 3.162E-12
K 5.624E-12
L 1.000E-11
M 1.778E-11
N 3.162E-11
O 5.624E-11
P 1.000E-10
Q 1.778E-10
R 3.162E-10

Figure 5A.13



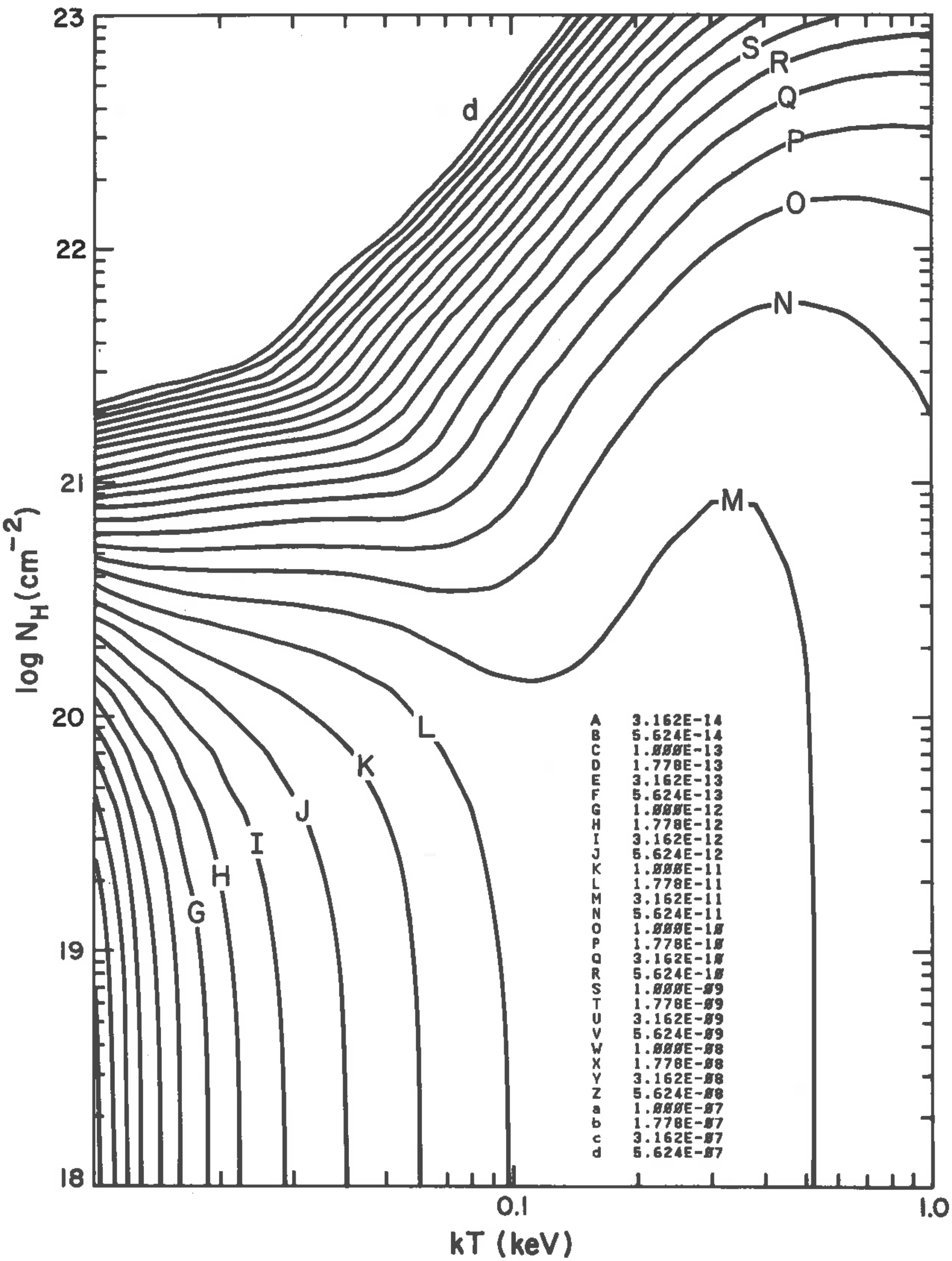
23
22
21
20
19
18
log N_H (cm^{-2})
0.1
1.0
kT (keV)
d
J
I
H
G
F
E
D
C
B
A
A 3.162E-12
B 5.624E-12
C 1.000E-11
D 1.778E-11
E 3.162E-11
F 5.624E-11
G 1.000E-10
H 1.778E-10
I 3.162E-10
J 5.624E-10
K 1.000E-09
L 1.778E-09
M 3.162E-09
N 5.624E-09
O 1.000E-08
P 1.778E-08
Q 3.162E-08
R 5.624E-08
S 1.000E-07
T 1.778E-07
U 3.162E-07
V 5.624E-07
W 1.000E-06
X 1.778E-06
Y 3.162E-06
Z 5.624E-06
a 1.000E-05
b 1.778E-05
c 3.162E-05
d 5.623E-05

Figure 5A.14



23
22
21
20
19
18
log N_H (cm^{-2})
0.1
1.0
kT (keV)
Q
P
O
N
M
L
K
J
I
H
G
A 3.162E-14
B 5.624E-14
C 1.ØØØE-13
D 1.778E-13
E 3.162E-13
F 5.624E-13
G 1.ØØØE-12
H 1.778E-12
I 3.162E-12
J 5.624E-12
K 1.ØØØE-11
L 1.778E-11
M 3.162E-11
N 5.624E-11
O 1.ØØØE-1Ø
P 1.778E-1Ø
Q 3.162E-1Ø

Figure 5A.15



23
22
21
20
19
18
log N_H (cm^{-2})
0.1
1.0
kT (keV)
d
S
R
Q
P
O
N
M
L
K
J
I
H
G
A 3.162E-14
B 5.624E-14
C 1.000E-13
D 1.778E-13
E 3.162E-13
F 5.624E-13
G 1.000E-12
H 1.778E-12
I 3.162E-12
J 5.624E-12
K 1.000E-11
L 1.778E-11
M 3.162E-11
N 5.624E-11
O 1.000E-10
P 1.778E-10
Q 3.162E-10
R 5.624E-10
S 1.000E-09
T 1.778E-09
U 3.162E-09
V 5.624E-09
W 1.000E-08
X 1.778E-08
Y 3.162E-08
Z 5.624E-08
a 1.000E-07
b 1.778E-07
c 3.162E-07
d 5.624E-07

Figure 5A.16