# The QDP/PLT User's Guide

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November 8, 1990

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## Acknowledgements

These days most non-trivial software packages have evolved over a long period of time and PLT is no exception.

The first program to bear the name of QDP was written in the late 1970's by Andy Szymkowiak for use by the X-ray group on a PDP 11/70 at Goddard Space Flight Center. Although I don't think that a single line of code has survived from that original version, I am grateful to Andy for that version, and hence for the basic idea of an interactive graphics program.

The QDP/PLT development flourished during my years at the Institute of Astronomy, Cambridge, U.K. I am grateful to Andy Fabian for being able to fund my stay there, and also for providing the stimulating environment where such working software could be developed. It is important that PLT was developed not as a software project, but rather to meet real needs in the analysis of data.

Now that I am at Marshall Space Flight Center, I would like to thank Martin Weisskopf for his continuing support of these efforts.

I am grateful to Tim Pearson for providing and for continuing to support the PGPLOT graphics package. PGPLOT is flexible, easy to use, portable and device independent.

Numerous other people have made contributions to PLT, ranging from simple comments, such as "it doesn't work when I do this", to actually providing the code for new features. Some of these people are mentioned in the on-line help file under the "history" subtopic. I would like to say thank you to all the people who have offered comments.

# Contents

# Chapter 1

# Introduction

## 1.1 Overview

The *Quick and Dandy Plotter (QDP)* program reads ASCII files containing various plotting commands and data. *QDP* then calls the *PLT* subroutine which then executes the commands and plots the data. At this point the "`PLT>`" prompt appears and the user can then proceed to enter additional PLT commands which can:

- Display information on about the interactive commands *via* `HElp`,
- Override various PLT defaults,
- Override the PLT commands found in the QDP file,
- Add/remove labels,
- Plot data with various combinations of lines, markers, and error bars,
- Change the appearance/style of the of the plot, for example converting all text into the Roman Font,
- Plot the data as a function of a different $x$ variable,
- Change the number of panels in which the data is plotted,
- Define models and to calculate the 'best fit' parameter values,
- Generate a hardcopy.

Thus the interactive PLT commands allow you to both tailor the plot to your needs/taste and to do some simple analyses of the data. PLT commands can be placed in the QDP file, in an indirect command and/or in a command array created by the calling program. For example, if you have a set of commands that you commonly use, then you can place those commands in a file, and then have PLT execute the commands that it finds in that file. Since exactly the same command syntax is used in all places, it is not necessary to learn a special programming language to write software that uses PLT. Programmers can try out PLT commands interactively to find a set that works best with the type of data being plotted, and then make these commands the default values.

The PLT software is highly portable. PLT uses the PGPLOT Graphics Subroutine Library written by T. J. Pearson at the California Institute of Technology. PGPLOT has been ported to many systems ranging from MS-DOS machines to UNICOS Crays. PLT is actively supported on VAX VMS, SUN UNIX, and NeXT systems. The code is in standard Fortran and so can easily ported to other systems and is running on MS-DOS, PRIME, and IBM RS/6000 systems.

This manual provides an overview of how to use PLT. Not all commands will be described in the overview, however, Appendix B includes the contents of the on-line help which does contain every command.

The rest of this introduction defines a few terms and the discusses the syntax conventions used. If you wish to quickly get started with using PLT, you should skip to the next chapter. Once you have mastered the basics, you should come back and read the following sections.

## 1.2 Definitions

PLT operates on quantities called *vectors* which can consist of one, two, or three columns in this rectangular array. If the data contains no errors, then each column is a vector. If the data contains symmetric errors, then it takes two columns to denote a single vector. Likewise if you have two sided errors (*e.g.*, +5,−2), it will take 3 columns to denote a vector. If one number in a vector has an error, then all numbers in that vector must have the same type of error. The vectors are independent of each other, and so some vectors can have errors and others can be without.

The PLT default is to make each vector an independent plot group. The PLT `SKip` command can be used if you have just two vectors and you wish to create several plot groups within those vectors.

*Viewport* denotes the physical area of the plotting surface that you are using. PLT (*via* PGPLOT) uses device-independent coordinates to denote the viewport, with (0.0,0.0) denoting the bottom left corner of the display surface, and (1.0,1.0) the top right corner.

PLT can be used to fit a model to the data. A *model* consists of one or more components which are added together. Each component must have one or more parameters; when fitting the data, the parameters are varied to minimize $\chi^2$. There is no way to multiply the built-in components together.

A *COD file* is an ASCII text file that contains a function written in the COD programming language. PLT allows you to define a model in which one of the components is a function contained a COD file. When FIT evaluates that component, the COD function is called and should return with the function evaluated for the current parameter set.

## 1.3 Syntax

PLT does not distinguish between upper and lower case. When matching the characters you type with possible commands, PLT only matches characters in the *shortest unique abbreviation* which, in this documentation, is denoted by upper case. Thus both `color` and `colour` will match the `COlor` command. Of course, some caution is required as `cosmopolitan` will also match `COlor`. As new commands are added, a previously acceptable abbreviation could refer to one of the new commands. To avoid such potential conflicts, you are encouraged to use three letter abbreviations.

In this documentation, a name in all lower case name is a mnemonic and should not be entered. For example, in `Rescale X xmin,xmax` both "`xmin`" and "`xmax`" should be replaced with numbers.

In PLT, arguments can be separated by a comma and/or any number of spaces and tab characters. Thus, the strings `1 2 3` , `1,2,3` , `1, 2, 3` , and `1 , 2 , 3` are all parsed as three arguments. Sometimes it is necessary to leave a placeholder that indicates an argument should be skipped. This is done by entering two adjacent commas. The string `1,,3` is parsed as three arguments with the second argument being null. Null arguments are often used to indicate that the current value should not be changed. If it is necessary to enter any special character as part of an argument, the argument should be enclosed in quote marks. The string `1,"2,3,4",5` would be parsed as three arguments and the second argument would be the string `2,3,4` .

PLT allows you to embed the simple mathematical operators, `+` , `-` , `*` , and `/` into numbers. Thus, the argument `2*3` would be parsed as 6. The numeric expression is evaluated from left to right; hence, the argument `1+2/4` is parsed 3/4 or 0.75. This syntax can be useful in QDP files. For example, suppose column 1 is the time in seconds, and you wish to plot time in hours. This can be done with a global edit that appends the string `/3600.` to the numbers in column 1.

The character `#` is used to denote a number. When you see this character, you should not type `#` , but rather replace it with a number. Likewise, the character `$` denotes a string. Optional arguments are enclosed in square brackets `[...]` . If an argument must be one of several discrete choices, the choices will be listed separated by vertical lines `|` .

# Chapter 2

# Basics

## 2.1 QDP Files

The quickest and most convenient way to use PLT is with a QDP file. A QDP file is an ASCII text file that contains a rectangular array of data. Since QDP files are ASCII they are easy to create and highly portable to different computer systems. All QDP files must contain a two dimensional array of data. The row-column location of a number in the file determines the row-column index in the data array passed to PLT. It is possible, but not necessary, to include QDP and/or PLT commands at the top of the QDP file. These commands often serve to document the data. All the QDP program does is to read the file, and to pass the information to the PLT subroutine.

In order to try out the examples in this chapter and the next, you should first create a "`DEMO.QDP`" file that contains the following:

```
1   1  16
2   4   9
3   9   4
4  15   1           ! Yes 15 and NOT 16
```

(`XANADU:[PLOT.QDP]DEMO.QDP` contains a pre-typed version of this file.) This example file contains no QDP or PLT commands. The QDP default is to assume that each column of numbers is a separate vector.

This example illustrates that QDP files can contain comments. Comments begin with the comment character `!` and continue to the end of the line. The above example contains the comment "`Yes 15 and NOT 16`". Comments are completely ignored. This documentation will often include a comment with the example commands. When trying out the command, you do not need to type the comment; however, if you do type it, then no harm will be done.

The QDP data lines are free format and the numbers can be separated by spaces, a comma, or tabs. Every row should contain the same number of columns; however, if some data are missing, you can enter the word `NO` instead of an actual number. QDP translates the `NO` into the PLT no-data flag; which will be ignored by PLT.

## 2.2 Plot the File

Once you have created a version of `DEMO.QDP`, you can run QDP with

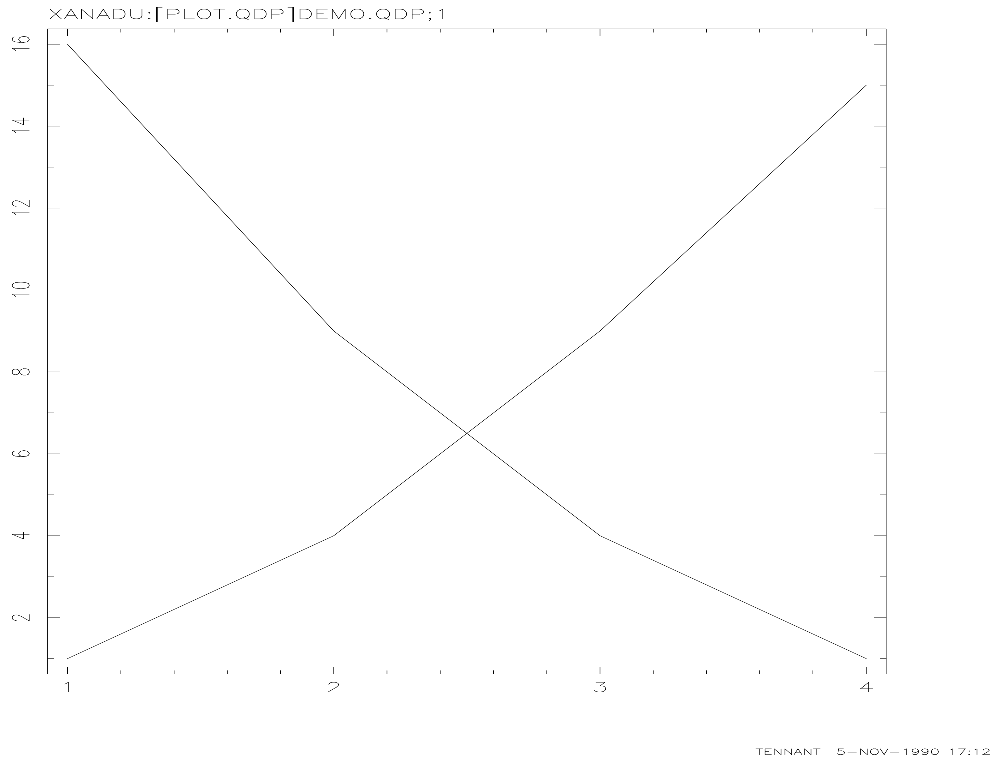



Figure 2.1: The default appearance of the `DEMO.QDP` file.

```
$ QDP DEMO
```

(If QDP fails to run, then you might need to define the QDP symbol as described in Appendix D, **Installation Guide**.) It is not necessary to enter the `.QDP` extension as the QDP program assumes that as the default. When the program starts, you will receive the following message:

```
To produce plot, please enter
PGPLOT file/type:
```

You should enter the PGPLOT specification for the device on which you wish to plot. If you do not know the device name, then enter `?` and all the device types supported by your local version of PGPLOT will be listed. If your terminal supports Tektronix graphics, then enter `/TE` to make the plot appear on your terminal. You might also try `/RE` for Retrographics. Most Tektronix emulators support the Retrographics extensions that allow the software to toggle between text and graphics modes.

A graph containing two lines will now be drawn as illustrated in figure 2.1. Since the file contained three columns of numbers, the default mode assumes there are three plot groups. The first plot group determines the $x$ coordinate. The next two columns are plotted as two lines. On a color display the first line will be red and the second green, which are the default colors for plot groups 2 and 3. The name of the QDP file appears in the top left of the plot and your userid, current date, and time appear in the bottom right of the plot. The `PLT>` prompt will now appear. In the following sections you will see how to enter various commands to change the default plot. The most useful command for beginners is the `HElp` command, which can be used to get instructions on how to use any command.

Another useful command is `EXit` that will get you out of the PLT subroutine. If you are in QDP, control will be returned to the operating system; in other programs, control will be returned to the calling program.

## 2.3 Rescaling

PLT chooses a default scale that makes all the data visible. The examples in this section will illustrate the `Rescale` command that can be used to change this scale. Using the plot created in the previous section, enter

```
PLT> R X 0 5
```

When you enter this command, the graph is redrawn with 0.0 on the left side and 5.0 on the right side of the viewport. Likewise `R Y 0 20` will put 0.0 on the bottom and 20.0 on the top. If you wish to change one number without the other, you can skip the field with commas or terminate the line before changing the default. For example, both

```
PLT> R Y 0 20    ! Set both lower and upper limit
```

and

```
PLT> R Y,,20     ! Set upper limit to 20, leaving lower unaffected
PLT> R Y 0       ! Set lower limit to 0, leaving upper unaffected
```

will produce the same effect. If you wish to change both the `X` and `Y` limits, then use

```
PLT> R 1 5 1 16  ! Set X-range to 1 to 5, and Y-range 1 to 16
```

If you wish to go back to the default scale, then use `R` with no arguments:

```
PLT> R Y         ! Will reset Y limits to default
PLT> R           ! Will reset both X and Y limits to default
```

At any time you can find out what the current scale limits are with

```
PLT> R ?
 Current Gap=   .025
Window   XLAB      XMIN        XMAX         YLAB       YMIN        YMAX
   1 :             .9250     ,  4.075     :             .6250     ,  16.38
PLT>
```

This produces a table of the current scaling parameters. The current gap is the default size of the gap between the edge of the data and the edge of the plot. For the default scale, the difference between the minimum/maximum and the data minimum/data maximum is due to the gap. With a gap of zero, the default minimum/maximum value will exactly match the data minimum/data maximum. The default is to plot all plot groups into just one window hence only one row appears in the table corresponding to that window. The columns labeled `XLAB` and `YLAB` contain the current $x$ and $y$ labels, which are currently blank.

If you want to see what the data minimum and maximum values are you should use

```
PLT> SHow Group

Grp  Wind    Label     XData Min     XData Max     YData Min     YData Max
  1    -1             :  1.000    ,   4.000     :  1.000    ,   4.000
  2     1             :  1.000    ,   4.000     :  1.000    ,   15.00
  3     1             :  1.000    ,   4.000     :  1.000    ,   16.00
```

The three rows correspond to the three plot groups. The column labeled `Wind` contains the window in which the group is currently being plotted, and a negative number indicates that the group is not actually plotted. In this example, group 1 is used to determine the $x$ coordinate and so is not actually plotted. The columns labeled `YData Min` and `YData Max` contain the actual data minimum and maximum of that plot group.

## 2.4 Making a Hardcopy

PLT makes a hardcopy by using the same PGPLOT routines but routed to a different graphics device. Thus the command does not make a hardcopy of what is currently on your screen, but rather, what would be plotted if you reissued the `Plot` command. The `HArd ?` command will display the name of your current default hardcopy device. It is possible to override this default when you enter the `HArd` command, thus `HArd /VPS` would make a vertical (portrait) mode Postscript file no matter what the default is. If you would like a different default than what is set up on your system, then you should define the logical name or on UNIX, the environment variable, `PLT_HARDCOPY` to contain the default you want. Let's assume the default is OK. So, merely enter

```
PLT> CSize 1.3   ! To increase the character size a bit
PLT> FOnt Roman  ! To use the nice looking Roman font
PLT> HArdcopy    ! To make a hardcopy file
```

PGPLOT would have now made a file in your current directory. You should consult your PGPLOT manual for the rules on how to print this file. On many systems it is possible to use the `@HARD` command that will both create a file and then spool the file to the printer.

The default PLT font is the Simple font because it plots the fastest. When you are making a hardcopy, speed is less important than quality. Therefore, you are encouraged to use the Roman font, which will give a more professional look to your hardcopy. As most journals greatly reduce the size of figures before printing, you should increase the character size. In the above example, `CSize 1.3` makes the character size a factor of 1.3 times larger than the default. The default line width is one, which is the thinest possible line. On some laser printers, this is too thin, and therefore, you should increase the line width, using the `LWidth` command. Using `LWidth 7` is not unreasonable for publication quality on some printers. In general the default hardcopy plot will fill the page on which it is being plotted. If a viewgraph was make of a full page plot, the projected size would overfill most screens. Therefore, it is useful to decrease the default size of the plot a bit. This can be done with the `Viewport` command. The default viewport is `.1 .1` which means the box containing the graph extends from 0.10 to 0.90 of the total physical plotting area. To make a plot half the size, use `View .3 .3`. `View .2 .2` will result in good size for most viewgraphs.

# Chapter 3

# Aesthetics

## 3.1 Labels

This chapter will describe the various options available to change the appearance of the plot. One of the most common things to do is to add labels, using the `LAbel` command. To put the label "Time (sec)" on the $x$-axis, "Distance" on the $y$-axis, and "My data" at the top of the plot,

```
PLT> LA X Time (sec)
PLT> LA Y Distance
PLT> LA T My data
PLT> P
```

You will notice that only certain PLT commands cause the graphics display to be updated. This allows you to enter several commands quickly without having to wait for the screen to be redrawn after each command. Whenever you want to see what the current graph looks like, you should enter the `Plot` command or just `P`.

There are also *Outer* labels (called `OX`, `OY`, `OT`) that can be used. These outer labels provide a simple way to create labels that need to lie on two lines. For example, the commands

```
PLT> LA X Universal
PLT> LA OX Time (sec)
PLT> P
```

would label the $x$-axis with two lines of text with the word "Universal" being written above the words "Time (sec)". Now what do you think the following command will do?

```
PLT> LA OT Fun! Fun! Fun!
PLT> P
```

If you try this you will find that only the word "Fun" appears. This is because `!` is the PLT comment character. If you wish to enter a PLT command that contains the comment character, then you must enclose the entire argument in quotation marks:

```
PLT> LA OT "Fun! Fun! Fun!"
PLT> P
```

To remove any label, enter the command with no text; thus,

```
PLT> LA OT
PLT> P
```

will remove the text "Fun! Fun! Fun!" from the graph. The name of the QDP file appears in the `File` position; thus the command `LA F` will remove this name. The timestamp that appears at the bottom of the plot can be removed with the `Time OFf` command and, of course, `Time ON` will turn it back on. In general, you should leave the file name and timestamp in place, as this information is very useful on a hardcopy. Sometimes, when working with a slow plotting device, you will want to speed things up by not plotting any labels. This can be done the `LAbel OFf` command. Of course, you should issue the `LAbel ON` command before making a hardcopy.

Text is drawn with PGPLOT; so the standard PGPLOT escape sequences are used. Hence, the commands

```
PLT> LA T \gx\u2
PLT> P
```

will label the top of the graph with $\chi^2$. The default font is the PGPLOT *Normal font*, which draws rather quickly. For journal quality text, you should override the default font with the `FOnt Roman` command. This will cause all text, including the numeric labels on the axes, to be written in the nicer looking, but slower plotting, Roman font. Use `FOnt ?` to get a list of possible fonts.

It is also possible to place a *numbered label* anywhere in the plot. To see this, try

```
PLT> LA 1 Pos 2 4 LIne -45 "Point at (2,4)"
PLT> P
```

The above command plots LAbel 1 at Position (2,4) with a LIne extending out at an angle of -45° to the $x$-axis and with the text message "Point at (2,4)". Each attribute can be set individually. Hence, if you decide you don't like the line extending downwards, you could change the angle with

```
PLT> LA 1 LIne 135
PLT> P
```

This leaves the pointing position and text unaffected, but resets the angle of the line (and also the justification of the string).

## 3.2 Vertical Plots

When you first plotted the `DEMO.QDP` file, two plot groups were plotted on the same panel. It is possible to plot each plot group on a separate panel in a vertical stack. To see this, try

```
$ QDP DEMO
(enter device type)
PLT> Plot Vertical
PLT> Plot
```

The `Plot Vertical` command resets the internal parameters so that each visible plot group will be plotted in a separate panel in a vertical stack. Nothing is replotted until the `Plot` command is issued by itself. This allows you to reset other parameters, without having to wait for a new graph to be drawn.

The $y$-scale can be adjusted in each panel separately. Hence,

```
PLT> R Y2 0 10
PLT> R Y3 0 50
PLT> P
```

will set the $y$ range of the top panel to be 0 to 10 and of the bottom panel to be 0 to 50. The `R ?` command can be used at any time to display the current ranges. At this point it would be wise to label each plot group. So enter

```
PLT> LA G1 x-axis
PLT> LA G2 group 2
PLT> LA G3 group 3
PLT> P
PLT> R ?
 Current Gap=   .025
Window   XLAB      XMIN        XMAX         YLAB      YMIN        YMAX
   2 : x-axis      .9250     ,  4.075     : group 2     .0000     ,  10.00
   3 : x-axis      .9250     ,  4.075     : group 3     .0000     ,  50.00
PLT>
```

The `R ?` prints out the beginning of each label and therefore, with a good set of labels, it is easy to keep track of what is plotted where.

At this point it is worth pointing out the difference between plot groups, and the rescale parameters. A plot group is a group of associated data points that cannot be displayed in different panels. The `Rescale` command affects the scale of the designated panel. Thus, `R Y2 0 10` will set the $y$-scale in the second panel to range from 0 to 10. For maximum compatibility with previous versions of PLT, the `Plot Vert` command plots group 2 on panel 2. A command like `LAbel G1` will associate a label with a plot group. Thus if you enter the commands `Xaxis 2`, `Plot Vert`, and then `Plot`, you will find that plot group 2 now determines the $x$-axis and hence the label "group 2" is now used as the $x$-label. Plot group 1 is now plotted in the top panel, with the same label "x-axis" which, of course, this is no longer correct.

To undo the effects of the `Plot Vertical` command, you should enter

```
PLT> Plot Overlay
PLT> P
```

The $y$-axis label is the label of the first plot group to be plotted in that panel. Since now more than one group appears in the panel, this is now longer most appropriate. To override the $y$-axis label in a given panel, use the `LAbel Y` command. In other words the `LA Y` command can be used to denote all the $y$ plot groups in a given panel, whereas `G1`, `G2`, *etc.* will associate a label with the specified plot group.

## 3.3 Colors, Lines, and Markers

The default mode of PLT is to plot group 1 with color index 1, group 2 with color index 2, *etc.* The `COlor ?` command can be used to generate a list of the default colors used to plot each color index. The command `COlor 3 ON 2` will cause color index 3 to be used with group 2 is plotted. With the PGPLOT default colors, this means that group 2 will now be plotted in green. It is important to realize that the `COlor` command changes the color index and only indirectly, the color.

Due to historical accident the `COlor` command can be used to prevent plot groups from being plotted. This is because color 0 corresponds to no-color or invisible. Thus `COlor 0 ON 2` will suppress the plotting of group 2. A cleaner way to do this is with the command `COlor OFf 2`. A `COlor OFf` command followed by a `COlor ON` command will restore the original color index. The `R Y` (with no arguments) command only uses plot groups that are visible to determine the default scale. For example, assume you are working with 6 plot groups and the values of groups 1 to 5 all lie in the range of 0.0 to 1.0, whereas the values in group 6 all lie near 100,000. For this example, the commands

```
PLT> COlor OFF 6
PLT> R Y
```

would redraw the graph, and the default $y$ range will lie between 0.0 and 1.0.

In the above examples, PLT drew a line between the points being plotted. If you wish to display the plot with markers, then you should turn on the plotting of markers with

```
PLT> MArk ON
PLT> P
```

For this example, the line connecting the various points disappears and only markers will be drawn. PLT draws a line when (a) all attributes (`LIne`, `MArker`, and `Errors`) are `OFF` or (b) the line attribute is `ON`. Thus if you want both the connecting line and markers to appear, then you need to turn on the `LIne` attribute with

```
PLT> LIne ON
PLT> P
```

The command `MArker Size 2` can be used to make the markers twice as big. The default marker style for all plot groups is type 2 as this marker plots very quickly. To change the style of the marker, try `MArker 9 ON 2` to use marker style 9 when plotting group 2. The command `MArker ?` will display a table of marker styles.

## 3.4 Log Scale

It is also possible to plot the data on a log scale. To do this, type

```
PLT> LOg Y
PLT> P
```

Use `LOg X` to use a log scale on the $x$-axis. The `LOg OFf` command will turn off the log scale on both the $x$- and $y$- axes. Note: Using `LOg` does not cause the data to be altered, only the appearance of the plot changes. If the lower limit of the scale being logged is negative or zero, then PLT will rescan the data searching for the smallest positive value, and make that the lower limit.

You should also be aware of the fact that the size of the gap, created by the `GAp` command is affected by log scale. Thus for a non-zero gap, the sequence `R X` followed by `LOg X` produces a different range than `LOg X` followed by `R X`. In the first case, the data minimum and maximum values are found, and then gap added in linear space. Applying the `LOg` command does not change this scale. In the second case, the scale is first logged, then the data minimum and maximum values are found. At this point the correct gap for a log plot is added.

# Chapter 4

# Fitting

## 4.1 Errors

This section describes a QDP file that contains errors and how to control plotting of those errors. The next two sections will describe how to define a model, find the best fitting parameter values, and then estimate the uncertainties on the parameter values. Although the examples will be based on the QDP file containing errors, it is possible (and sometimes better) to fit data without errors.

You should now create a `DEMO1.QDP` file that contains the following:

```
READ Serr 1 2
LAbel X Time
LAbel Y Distance
 1.0  .25   1.24  .3
 1.5  .25   1.86  .3
 2.0  .25   3.76  .3
 4.0 1.75  16.43  .3
 7.0 1.25  49.06  .3
```

The first line in this file is not a PLT command but rather a QDP command. The QDP `READ` command is used by QDP to tell PLT which vectors contain errors. In this case the READ command tells QDP that vectors 1 and 2 will have symmetric errors; hence, columns 1 and 2 contain data and errors for vector 1, and columns 3 and 4 contain data and errors for vector 2. Following the QDP command are two PLT commands that will be passed to the PLT program and executed before the graph is drawn. Including PLT commands in the QDP file provide a way to override built-in defaults and/or to add labels to the graph. Data lines occur after all the command lines. To read and plot this file, use

```
$ QDP DEMO1
(enter device type)
PLT>
```

The graph that looks like figure 4.1 should now appear. When you plot data containing errors, the error attribute is `ON`, and the errors plotted. As described in section 3.3, the line will no longer appear connecting the data. If you want to see that line, then should use `LIne ON` to explicitly switch on the line. To suppress plotting of the errors use,

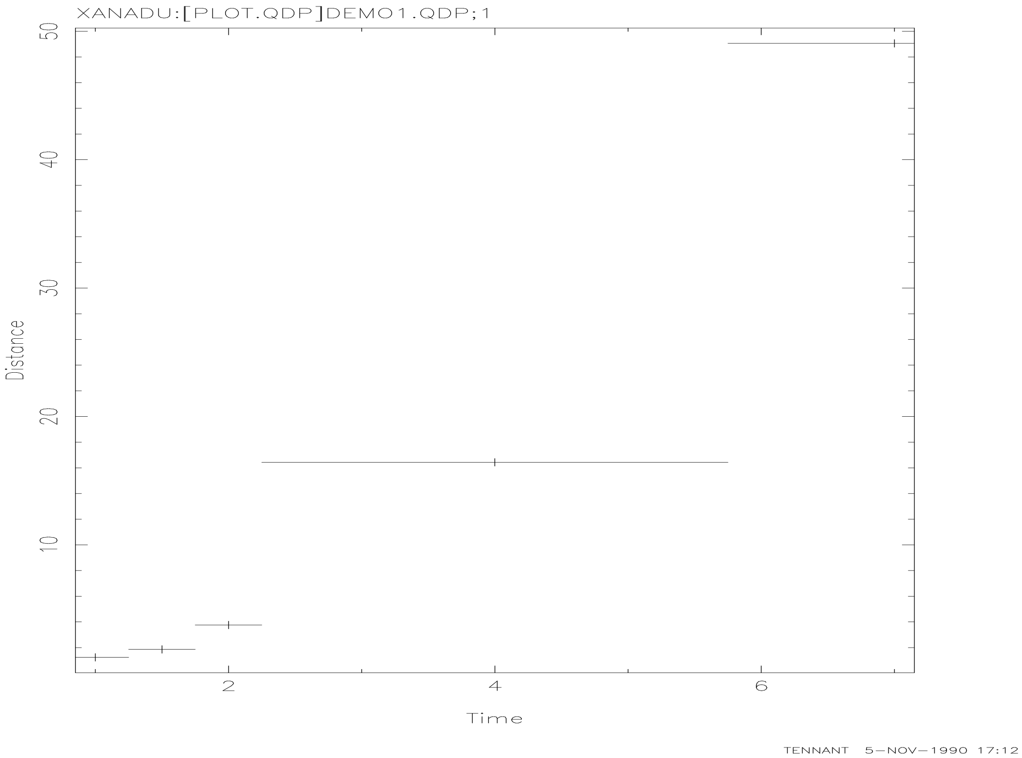



Figure 4.1: The default appearance of the `DEMO1.QDP` file.

```
PLT> Error OFf
PLT> P
```

This causes the error bars not to be plotted; once again the line connecting the points appears. You should now enter

```
PLT> LIne Step
PLT> P
```

to produce a stepped-line plot. Using `Error ON` at this time will cause both the stepped line and the errors to be plotted. This is because the `LIne Step` command sets an internal flag that a line should be plotted and the `Error ON` command sets another flag to plot errors. The command `LIne OFf` will turn off the plotting of the (stepped) line. The plotting of a line, errors and markers can all be turned on or off for each vector independently. You should see the `LIne`, `Error` and `MArker` commands, in Appendix B, **PLT Command Summary**, for more information.

## 4.2 Fitting

This section requires the `DEMO1.QDP` file described in the previous section. Before you can fit data, you must first define a model. First, read in the data and define a constant model with

```
$ QDP DEMO1
```

```
(enter device type)
PLT> MOdel CONS
```

At this point, you will be prompted for the default initial value for the constant. Enter Return to use the default, and at the `PLT>` prompt, type `Fit`.[1] When `Fit` runs, it first tells you which plot group is being fitted and the range over which data are being fitted. It is important to realize that if you have used `R X` to rescale the $x$-axis so that some points are outside the range plotted, then these points would not be included in the fit. You cannot exclude points using the `R Y` command. (This is intended to prevent cheating.) You will next see the message "Fitting 5 points in a band of 5". This informs you that there are 5 points in the current $x$-range. In order to execute faster, the FIT routine resets the minimum and maximum of the array, to achieve the smallest range possible that includes all points in the $x$-range, and so the "band of 5" output informs you how big this minimum range is. Next the FIT routine prints the current parameter values (1.00000 in this case). The program then prints the current value of the weighted variance `W-VAR`. If you have errors on your data, the weighted variance is $\chi^2$; for no errors, `W-VAR` is just the variance. The number in `()` is $\log \lambda$ and is for the expert's use.

The *CURFIT* routine will terminate when the change in $\chi^2$ or, for an unweighted fit the relative change in the variance, is less than 0.05. If this condition has not been met after 10 iterations, you will be prompted "`Continue fitting? (n)`". Answer `Y` to continue or `N` to terminate. If you are are fitting in background or batch mode, then you should always leave a blank line after the `Fit` command. Thus if `Fit` does not terminate, the "`Continue fitting? (n)`" question will read the blank line with the default answer of no and terminate. If the fit does terminate, PLT will see the blank line, and ignore it. When *CURFIT* terminates the current parameter values are again printed and this model is drawn on the current plot.

For the above, the total variance is 18323 and hence a CONS does not look like a very good model. Let's try a more complicated model with

```
PLT> MOdel CO LI QU
```

to include constant, linear and quadratic components. Again you can default on all the initial values. When you type `Fit`, you should find that `W-VAR` has decreased to 4.23. This is clearly a better fit.

To generate a list of all possible built-in components, use the `MOdel ?` command. To get a description of what a component does, use the `HElp MOdel` command followed by the component name. If you can not construct your model from the built-in components, then you can create additional components. A COD file can be used to define a sophisticated component. COD files are ASCII text files that contain functions written in a Forth-like computer language. Chapter 7 and Appendix A describe COD in some detail. If your component is too complicated for COD, or you don't like using COD, then you can create a Fortran function that can be used as a new component. The next chapter will describe how to create this function `UFNY`, and the supporting routines to replace the built-in `DEMO` component.

[1]The *FIT* subroutine minimizes $\chi^2$ using a modified version of Bevington's *CURFIT* subroutine. Bevington's book *Data reduction and Error Analysis for the Physical Sciences*, published by McGraw-Hill in 1969, is an excellent introduction to statistics. Anyone interested in a detailed understanding of how CURFIT works should consult this book.

It is possible to save the current model to a disk file using the `WModel` command. For example,

```
PLT> WModel DEMO1
```

will create a `DEMO1.MOD` file. To read this model back into PLT use the command `MOdel @DEMO1`. Model files can be printed out to make a hardcopy of the current parameter values. If you do not enter a file name with the `WModel` command, then the model is written to your current terminal screen.

## 4.3 Parameter Uncertainties

The `Uncertainty` command can be used to estimate the uncertainties in the parameter values.[2] To try this, you should first fit the data in the `DEMO1.QDP` file to a `CO LI QU` model, as described in the previous section. Now enter the command

```
PLT> Uncertain 1
```

The program will now change the value of parameter 1 by a small amount and recompute $\chi^2$. At each step, the delta parameter value and the $\Delta\chi^2$ are printed out. For complicated models it may take many steps before the desired value of $\Delta\chi^2$ is found. The program considers both positive and negative delta parameter values. The default value of $\Delta\chi^2$ is 2.7 which corresponds to the 90% confidence range for a single parameter.

With the `DEMO1.QDP` file you will find that both parameter 1 and 2 are consistent with zero. To see if they can be eliminated, try the following:

```
PLT> Newpar 1,0,-1
PLT> Newpar 2,0,-1
PLT> Fit
```

The first command resets both the `VAL` and `SIG` terms of parameter 1 to be 0.0 and -1.0, respectively. A `SIG` of -1.0 means that the parameter is frozen and hence not allowed to change. Note: The command `Newpar 1,,-1` would have frozen parameter 1 at its current value. The second line freezes the value of parameter 2 to be zero. The results of the `Fit` reveal that $\chi^2$ has increased by 0.55 and the $F$-statistic or a likelihood ratio tells us that these two components were not required by the model.

The `Uncertainty` command is fairly robust but on occasion can have difficulties. Sometimes, `Uncertainty` will find a new minimum value of $\chi^2$. This causes the search to be stopped and the parameter values to be reset. At this point, you should reissue the `Fit` command to locate precisely the new minimum. Sometimes, `Uncertainty` will be unable to locate the requested value of $\Delta\chi^2$ after 10 tries. At this point the message `UNCERT--Give up.` is printed. It will be up to you to decide if the error has been correctly calculated. Finally, the `Uncertainty` command uses the `SIG` value to estimate the location of the error. If this number is greatly in error, then `Uncertainty` will be start it's search in the wrong place. If this occurs then it is sometimes possible to adjust `SIG` to be a more accurate estimate, before issuing the `Uncertainty` command.

[2]Uncertainties in parameter values are estimated using the method described in "Parameter Estimation in X-ray Astronomy", by M. Lampton, B. Margon, and S. Bowyer, in *Astrophysical Journal* (1976) **208**, 177.

It is also possible that the `SIG` is inaccurate because the true minimum has not been found and further fitting is needed.

# Chapter 5

# Miscellaneous

## 5.1 PLT Command Files

PLT commands can also be entered *via* a command file. For example, if you often enter the sequence of commands `FOnt Roman` followed by `CSize 1.3`, then you could create a file called `NICE.PCO` that contains the lines

```
FOnt Roman
CSize 1.3
```

To execute these commands inside PLT, all you need to type is

```
PLT> @NICE
```

(A default file extension `.PCO` is assumed.) Thus command files provide a way to enter several and/or complicated commands easily.

Note that the reference to a command file is a legal PLT command that can appear in a QDP file. Since this is a PLT command, QDP itself will not open and read the command file. Hence, QDP commands and data lines cannot be entered *via* a command file. Command files serve two important uses in QDP files. First, they provide a way to enter the same set of commands to several files. Second, for long data files, editing the QDP file can be tedious. Hence, you can edit it once to enter a reference to the command file. Thereafter, whenever you want to change the PLT command list, you only need to edit the command file.

PLT searches up to three different directories for the specified indirect command. The current directory is always searched first. If the file is not found in the current directory then PLT tries to translate the logical name (under VMS) or environment variable (under UNIX or DOS) called MY_XCOMS. If MY_XCOMS has been defined, then PLT searches the specified directory. If the file still has not been found then PLT searches the `XANADU:[LIB.XCOMS]` directory. This three level search allows you to create system-wide files, user-wide files, and directory specific files. For example, many locations create a file `HARD.PCO` in the `XANADU:[LIB.XCOMS]` directory that (1) creates a hardcopy file and (2) spools the file to the printer (done using the `$` command to spawn a job to spool the plot to the printer). This then allows all users on that system to use

```
PLT> @HARD
```

to immediately print a hardcopy. If you do not like something about the existing `@HARD` command then you can easily create a new private version of this command. First copy the file to one of your own directories, modify the file, and define MY_XCOMS to contain the name of the directory containing the new version. Once this has been done, PLT will find and run your version of the command instead of the system installed version.

It is possible to use parameters with indirect command files. The parameter values are entered on the same line that opened the indirect command file. Thus,

```
PLT> @test one two three
```

would cause plt to open and read the `TEST.PCO` file with three parameters "`one`", "`two`", and "`three`". If `n` is a number then the sequence `%n%` will be replaced with the nth parameter. For the above example, `%1%` will be replaced with '`one`', `%2%` with '`two`', *etc.* The following illustrates a possible indirect file that could use up to three parameters:

```
LABel X %1%
LABel Y %2%
LABel T %3%
```

If you fail to enter all three parameters, then `%n%` will be replaced with a null string for the unentered parameters.

It is possible for one indirect file to call another indirect file and pass in parameters. Thus,

```
@deeper first %2% %3%
```

is a valid line in an indirect command file. In this example, the first parameter is "`first`", whereas the next two parameters will be set equal to parameters 2 and 3 of the current script. Also quotes can be used to denotes a single parameter with embedded spaces, or other 'magic' characters. Thus the line,

```
@file "This is all one" two three
```

contains three parameters, and the first parameter is the string '`This is all one`'.

## 5.2 Version Control

New features are constantly being added to PLT, and so it is important track of these changes. There are three places where changes are noted. First, the PLT `VErsion` command can be used to identify the date of the most recent change to version of PLT linked into the program you are using. If certain commands do not appear to work then you should check this number. Often you will find that the program has not been linked for a while and as a result the command that you are trying to use was added after the last link.

The second place version numbers are recorded is in the on-line help file. The `HElp VErsion` command will list all recently added new features and when they were made. A serious attempt is made to ensure that on-line help is updated as the software is modified. For best results on your system, you should also update the on-line help every time you update PLT itself. However, there is no requirement for these two version numbers to match. Thus, when you install a new version of PLT it is not necessary to immediately relink all software that uses it.

Finally the printed manual is updated about once a year. Therefore, the printed manual can be slightly out of date.

# Chapter 6

# Fortran interface

## 6.1 Programming PLT

After using the QDP/PLT software for a while, some people would like to see more sophisticated features such as the ability to read binary files, or to add different vectors together. Although the author is always willing to take suggestions (and even to implement some of these suggestions), the PLT design goal is to implement new features in as a general manner as possible. Thus if you have a need to read a particular file format, or to manipulate data in a particular manner, you should implement your own front end to the PLT subroutine. This is simple to do since the QDP program cleanly separates reading of the file from actually calling the PLT routine.

This chapter describes how to call the RDQDP and PLT subroutines. Also listed is the complete source code for the QDP program. Although QDP can be used as an example of how to call PLT, it is perhaps too simple. Therefore the DEMO Fortran program more clearly shows how to do this. Finally there are instructions on how to create your own user defined function that when linked with the QDP/PLT software can be used with the `Model` and `Fit` commands.

Although PLT uses several other internal routines, you are discouraged from directly using these routines in your code. This is because PLT continues to evolve, and there is no way that the author add the functionality required without the ability to modify the internal interfaces. There are no plans to modify the calling sequence for all the routines described in this chapter.

## 6.2 Subroutine RDQDP

The calling sequence for the `RDQDP` subroutine is:

```
      SUBROUTINE RDQDP(ICHAT, LUNIN, CNAM, Y, MXPTS, IERY, MXVEC,
     :   NROW, NPTS, NVEC, CMD, MXCMD, NCMD, IER)
      INTEGER   MXPTS, MXVEC, MXCMD
      CHARACTER CNAM*(*), CMD(MXCMD)*(*)
      REAL      Y(MXPTS)
      INTEGER   IERY(MXVEC)
      INTEGER   ICHAT, LUNIN, NROW, NPTS, NVEC, NCMD, IER
C---
C Opens and reads a QDP file.
C---
C ICHAT      I    >10 means print comment lines, >0 print row/col info.
C LUNIN      I    <>0 means file already open on LUN.
C CNAM       I/O  File name.
C Y            O  The data array
C MXPTS      I    The actual size of the Y array.
C IERY         O  The PLT error flag array
C MXVEC      I    The actual size of the IERY array
C NROW         O  Maximum number of rows that the file could contain.
C NPTS,NVEC    O  Needed by PLT
C CMD          O  Command array (MXCMD input dimension).
C NCMD         O  Number of commands read
C IER          O  =-1 if user entered EOF, =0 file read, =1 no file read.
```

There are several ways to specify a file to be read by RDQDP. RDQDP will go through the following steps to determine what file to read. Once a file has been determined the remaining steps will be skipped. Specifically RDQDP will do the following:

- If the variable `LUNIN` is non-zero then RDQDP will assume that the input file has already been opened and is attached to the specified unit number.
- If the variable `CNAM` is non-blank, then RDQDP opens a file with the specified name.
- At this point it is necessary to obtain a file name from an external source and the parser is called to handle this. If this is the first time the parser has been called in the current program, an attempt will be made to read the command line. If a QDP file name is found on the command line, then that file is opened.
- If no file name could be found, or the file could not be opened, then RDQDP will prompt the user for an input file name. If the user enters an end-of-file (`^Z` under VMS, or `/*` under all systems), then RDQDP will exit with `IER`=-1. If the user enters a blank line for the file name, RDQDP will exit `IER`>0. Of course, if the user enters a valid file name, then that file is opened, and `IER` will return a value of 0.

Once a file has been opened, and if `MXCMD`>1, RDQDP will add a `LAbel F` command to the `CMD` array that contains the name of the file actually opened. Of course, if the file contains a `LAbel F` command, then that command will overwrite the label that RDQDP creates.

`ICHAT` is the 'chatter' flag. If `ICHAT`>10 then RDQDP will display lines that have `!` in the first column, on your terminal screen. Displaying these lines, provides a useful way to confirm that RDQDP has opened the correct file. Such comment lines are completely ignored, and the comments will be removed from any other line containing a comment. RDQDP examines the beginning of each line and if the line contains a QDP command, RDQDP proceeds to interpret the command and set the appropriate variables to be passed to PLT. If the line starts with a PLT command and `NCMD`<`MXCMD`, then RDQDP will increment `NCMD` and add the line to the `CMD` array. For lines containing data, RDQDP interprets the line into real numbers and stores these numbers in the `Y` array.

The RDQDP routine does not open and read any indirect command files, but just stores the command in the `CMD` array. Therefore you cannot use an indirect command file to contain the data array. Since the calling program determines the size of the `CMD` array it is sometimes useful to store all PLT commands in an indirect command file and to add one line to the QDP file to read the indirect file. When PLT reads an read indirect file it will accept command lines up to 250 characters long, and there is no limit on the number of lines that can be read.

When RDQDP reads the first data line, it determines the number of columns in that line. Based on this number of columns, and the size of `MXPTS` passed in, RDQDP proceeds to calculate the maximum number of rows that would fit into the `Y` array. If the `ICHAT`> 0, RDQDP will then display on the terminal, the number of columns, the numbers of vectors (calculated from the data from in any `READ` lines), and the maximum number of rows.

## 6.3 Subroutine PLT

The calling sequence for the PLT subroutine is:

```
      SUBROUTINE PLT(Y, IERY, MXROW, NPTS, NVEC, CMD, NCMD, IER)
      REAL      Y(*)
      INTEGER   IERY(*), MXROW, NPTS, NVEC, NCMD, IER
      CHARACTER CMD(*)*(*)
C---
C General plot subroutine.
C---
C Y(*)      I    The data array.  The array should be dimensioned
C                Y(MXROW,MXCOL) where MXROW and MXCOL are the actual
C                sizes of the arrays in the calling program.
C                MXCOL=NVEC+NSERR+2*NTERR  where NSERR is the number
C                of vectors that have symmetric errors and NTERR
C                is the number of vectors that have two-sided errors.
C IERY(*)   I    =-1 plot errors as SQRT(Y)
C                = 0 no errors.
C                =+1 explicit symmetric errors.
C                =+2 for two-sided errors
C MXROW     I    The actual first dimension of the Y array.
C NPTS      I    The number of points to plot (NPTS<=MXROW).
C NVEC      I    The number of vectors to be plotted.
C CMD(*)    I    Array of commands.
C NCMD      I    Number of commands.
C IER         O  Error flag, =-1 if user entered EOF, =0 otherwise.
```

It is important to remember that the variable `NVEC` does not refer to the number of columns of data but rather the number of vectors. Each vector must have one entry in the `IERY` array that describes the type of error on that vector. Depending on the type of error, each vector can be composed of one, two, or three columns of data. To calculate the number of columns needed by the vectors, let `NSERR` be the number of vectors with symmetric errors (`IERY(I)`=1) and `NTERR` the number with two sided errors (`IERY(I)`=2). The total number of columns `MXCOL` will be given by `MXCOL=NVEC+NSERR+2*NTERR`.

The variable `MXROW` contains the physical first dimension of the `Y` array. Thus the calling program should dimension `Y` to be `(MXROW,MXCOL)` or the Fortran equivalent `(MXROW*MXCOL)`. The variable `NPTS` contains the number of rows that contain valid data. All rows from `NPTS+1` to `MXROW` will be ignored. When PLT starts it will execute `NCMD` lines from the `CMD` array. Any valid PLT command can be entered into this array. For example, one line could contain a reference to an indirect command file, and this would cause PLT to execute all commands found in this file. If the command list contains the `EXit` command, then PLT will exit when this command executes and any commands following the `EXit` will be ignored. Since PLT does not actually plot any data until all the commands are executed, it is a good idea to precede an `EXit` with a `Plot` command, since that will force a plot to be produced.

If PLT exits normally, *i.e.*, with the the `EXit` command, then `IER` is set to zero. If the user enters an end-of-file then PLT exits with `IER`<0.

## 6.4 The QDP program

The complete source code for the `QDP` program is:

```
C Program QDP, the Quick and Dandy Plotter.
C Reads and plots a QDP file.
C---
C [AFT]
C---
      INTEGER   MXPTS, MXVEC, MXCMD
      PARAMETER (MXPTS=131072)
      PARAMETER (MXVEC=64)
      PARAMETER (MXCMD=50)
C
      CHARACTER CMD(MXCMD)*100
      CHARACTER CNAM*72
      REAL      Y(MXPTS)
      INTEGER   IERY(MXVEC)
      INTEGER   ICHAT, IER, LUN, NCMD, NPTS, NROW, NVEC
C---
  100 CNAM=' '
      ICHAT=0
      LUN=0
      CALL RDQDP(ICHAT, LUN, CNAM, Y, MXPTS, IERY, MXVEC,
     :   NROW, NPTS, NVEC, CMD, MXCMD, NCMD, IER)
      IF(IER.NE.0) GOTO 900
      CALL PLT(Y,IERY,NROW,NPTS,NVEC,CMD,NCMD,IER)
      IF(IER.LT.0) GOTO 100
C---
  900 CONTINUE
      END
```

The QDP program calls the RDQDP subroutine to read the QDP file, and then passes the data read to PLT. The parameter statements show that this version can read a file containing up to 131,072 numbers, up to 64 different vectors, and up to 50 PLT command lines. RDQDP sets creates array dimensions to make maximum use of the data array. For example, if you read a file containing two columns, then you could read up to 65536 rows of data. If the file contains 64 vectors and none of the vectors contains errors *i.e.*, there are 64 columns of numbers, then the maximum number of rows will be 2048. If, however, all 64 vectors contain two-sided errors, then only 512 rows can be read. Each PLT command line can be at most 100 characters long.

QDP sets both `CNAM=' '` and `LUN=0` to force RDQDP to prompt for a QDP file name. If the file is opened, then RDQDP proceeds to read the file, and initializes all the variables needed by the PLT routine. If RDQDP has set `IER`=0 then some data has been read and hence the PLT routine is called.

PLT interprets the PLT commands and plots the data. If the user enters an end-of-file character at the `PLT>` prompt, PLT exits with `IER`=-1. This causes the QDP program to loop back and call RDQDP again. For a normal exits, `IER`=0, the QDP program quietly exits.

## 6.5 The DEMO program

The file `XANADU:[PLOT.QDP]DEMO.FOR` contains a simple Fortran program that creates the necessary arrays and then calls the PLT subroutine. The complete source code for the `DEMO.FOR` program is:

```
C---
C DEMO.FOR demonstrates how to call PLT from a Fortran program.
C---
C [AFT]
C---
      INTEGER   MXROW, MXCOL, MXVEC, MXCMD
      PARAMETER (MXROW=200, MXCOL=3, MXVEC=2, MXCMD=10)
      CHARACTER CMD(MXCMD)*72
      REAL      Y(MXROW, MXCOL)
      INTEGER   IERY(MXVEC), NVEC, NPTS, NCMD, IER
      INTEGER   I
C---
C Create two vectors.  The first vector will contain the X locations
C and a symmetric error (with constant value of 0.5).  The second
C vector will contain X*X and no error.
      NVEC=2
      IERY(1)=1
      IERY(2)=0
      NPTS=100
      DO 190 I=1,NPTS
         Y(I,1)=I
         Y(I,2)=.5
         Y(I,3)=Y(I,1)*Y(I,1)
  190 CONTINUE
C---
C Now add a couple of commands, to make plot look nicer.
      CMD(1)='LAB X Time (sec)'
      CMD(2)='LAB Y Distance (m)'
      CMD(3)='LAB T Made with DEMO.FOR'
      CMD(4)='LINE STEP 2'
      NCMD=4
C---
C Call the PLT subroutine.
      CALL PLT(Y, IERY, MXROW, NPTS, NVEC, CMD, NCMD, IER)
      END
```

`DEMO.FOR` was written as an example to show how the various parameters are initialized before calling PLT. In the program `NVEC=2` tells PLT to expect two vectors; `IERY(1)=1` tells PLT that the first vector contains symmetric errors and, hence, is composed of two columns; and `IERY(2)=0` tells PLT that the second vector does not have errors. The `DO 190` loop fills 100 points of these two vectors. The `Y` array is large enough to contain up to 200 points. The first column of the `Y` array contains the $x$-value, which run from 1 to 100; the second column contains the errors (constant value 0.5); and the third column contains $x^2$. After the `Y` array is initialized, the `CMD` array is initialized with four PLT commands. The first three commands define labels, and the last command creates a stepped-line plot.

The file `XANADU:[PLOT.QDP]DEMO.COM` will compile and link the `DEMO.FOR` program on a VMS system. This file can be used as an example for linking other routines that call PLT. It is necessary to link with both the XANLIB library and also the PGPLOT graphics library.

## 6.6 A user function

The calling sequences for the four subroutines required to create a user component are:

```
      SUBROUTINE UINFO(IPAR, CNAME, NPAR)
      INTEGER   IPAR, NPAR
      CHARACTER CNAME*(*)
C---
C IPAR    I    The parameter number.
C CNAME     O  The name of the parameter IPAR.  Note if IPAR=0, then
C              -return the name of the model.
C NPAR      O  The number of parameters in your user model.
C---
C*********
      SUBROUTINE ULIMIT(PVAL, PLIM, NT, NPAR)
      REAL      PVAL(*), PLIM(3,*)
      INTEGER   NT, NPAR
C---
C PVAL(*)   I/O  The current parameter values
C PLIM(1,*) I    If <0 then the corresponding parameter is frozen
C NT        I    Pointer to first parameter value in array PVAL(*)
C NPAR      I    Number of parameters
C---
C*********
      REAL FUNCTION UFNY(X, PVAL, NT, NPAR)
      REAL      X, PVAL(*)
      INTEGER   NT, NPAR
C---
C X       I    The current X value
C PVAL    I    The current parameter values
C NT      I    Pointer to first parameter value in array PVAL(*)
C NPAR    I    Number of parameters
C---
C*********
      SUBROUTINE UDERIV(X, PVAL, PLIM, DERIV, NT, NPAR)
      REAL      X, PVAL(*), PLIM(3,*), DERIV(*)
      INTEGER   NT, NPAR
C---
C X       I    The current X value
C PVAL    I    The current parameter values
C PLIM    I    The constraints array
C DERIV     O  The calculated derivative
C NT      I    Pointer to first parameter value in array PVAL(*)
C NPAR    I    Number of parameters
C---
```

The file XANADU:[LIB.UFNY]UFNYDEMO.FOR contains the source code for the built-in DEMO user component. You should copy that file and use it as a template for any file that you create.

When FIT starts, it calls UINFO with IPAR set equal to 0 to get the name of the user component and the number of parameters. This component name will be included in the names of the built-in components, and therefore, should not match any existing component name (such as CONS, LINE, etc.) If the user component is selected, then UINFO will be called for each parameter to get the name of that parameter.

ULIMIT is always called after any parameter values have been changed and before UFNY is called. The purpose of ULIMIT is two-fold. First, it should check the parameter values in PVAL and adjust any that may cause a problem in UFNY (for example, if UFNY divides by a parameter value, then ULIMIT should ensure that the parameter does not equal zero). Second, ULIMIT can be used to set up any initial data that UFNY needs. Since, UFNY is often called many times with the same parameter set, this can result in a speedup. The parameter values are stored in PVAL(NT) to PVAL(NT+NPAR-1). The PLIM array contains SIG, PLO, and PHI. If PLIM(1,I) is less than zero, then that parameter is frozen and you should not adjust the parameter value. Also, if PLIM(2,I)<PLIM(3,I), then an effective range is active and you should not adjust a parameter outside that range.

UFNY is the function that actually calculates user component at location X with parameter values given by PVAL.

UDERIV should calculate the derivative of the UFNY function with respect to each parameter. The version contained in UFNYDEMO.FOR evaluates the derivative numerically and hence you may be able to use it without modification. If you use that method you should try to scale the problem so that parameter values are in the range .1-100, values outside this range work, but the convergence can be slower.

If PLIM(1,I)=-1 then that parameter is frozen and hence you do not need to calculate the derivative. If PLIM(1,I)<-1 then the parameter has been set equal to another parameter and you should calculate the derivative in the normal manner (the FIT routine assumes that the derivative has been correctly calculated).

If you able to compute the analytic derivative of your function with respect to the parameter values, then you should use it, as an accurate derivative can greatly improve the fitting process. NOTE, slow convergence is most often due to the derivative being incorrectly calculated. If you find that $\chi^2$ drops slowly, and that FIT is unable to precisely locate the minimum, then you should carefully check both your equations and the UDERIV implementation for typical errors, such as an incorrect sign.

Once you have a working function, you should test it in PLT. Use the MOdel ? command to see if your component is listed. If not make sure you have linked a new version, and that your are running that new version. Next define a model that is composed only of your new component, and enter a resonable set of parameters. Do not attempt to fit at this time, but rather just plot the data and model. Use the Fit Plot 200 command to ensure that the function is evaluated at 200 points over the visible range. Is the plotted function what you expected? If it is not then you should carefully examine your code.

Once the function is doing what you expect, then you can try to fit it. If certain parameter values can cause a program crash, then you should write a version of ULIMIT that prohibits these values.

# Chapter 7

# COD

## 7.1 Introduction

The `COD` program has been designed to fill two roles. First, it can be used like a programmable calculator. In this mode you can use the computer to do simple calculations (on days that your calculator is down). Second, it is designed to assist in developing and testing COD functions that can be used as components in PLT models.

This chapter will assume that you want to create a COD file that can be used with PLT. If you have no previous experience with COD, then you should start by running the `COD` program and learning how to use the stack and various built-in functions. (In COD, functions are sometimes called *words*.) Next you should create and use some simple *colon definitions* within `COD` itself. Colon definitions are the way one creates new functions. COD files contain ASCII text in the same form as you would type in interactive mode. A file that can be used as a model component by PLT is nothing more than a COD file containing a colon definition and supporting code. The `COD` program provides tools for the reading and testing of functions contained in COD files.

## 7.2 Interactive mode

The best way to learn about COD is to run the `COD` program and experiment. This can be done with

```
$ COD
Type HELP for help.

COD>
```

When COD starts, it first prints information on how to get help, followed by a blank line. The blank line actually displays the contents of the stack, which is initially empty. Finally, you get the "`COD>`" prompt. At this prompt you can type `HElp` to obtain interactive help on the various commands and how to use them.

The first thing you will want to do is to enter a number into the stack. This is done by typing the number and then pressing the $\boxed{\text{Return}}$ key. For example, to enter the number `2` into the stack,

```
COD> 2
 2.0
```

COD echos the stack and then returns the COD prompt. (In this documentation the final prompt is not shown.) To execute a simple mathematical function enter, all the numbers required by the function and then the function itself. The following sequence shows how to multiply the previously entered `2` by the number `3` to obtain `2*3`:

```
 2.0
COD> 3
 2.0 3.0
COD> *
 6.0
```

With COD it is not necessary to enter one token (number or function) per line. Tokens may be entered, separated by spaces, on a single line. Hence, to divide the result of the previous calculation by `0.5`, enter

```
 6.0
COD> .5 /
 12.0
```

COD contains several commands to manipulate the stack. Thus `SWap` will swap the top two numbers on the stack, and `DUP` will duplicate the top number on the stack. When using COD interactively, you will sometimes wish to clear out the stack. The can be done using the `ABOrt` command. Thus,

```
 12.0
COD> ABOrt

```

and the blank line indicating an empty stack will again appear just before the following COD prompt. There are a large number of built-in COD functions. To obtain a list of the functions, you may use the `List Dictionary` command. If you see a function and would like more information on what it does, you should use the `HElp Dictionary` command. For a complete list of built-in COD commands, consult Appendix A.

## 7.3 Colon Definitions

When running COD interactively, it is sometimes necessary to enter the same sequence of tokens several times. For such cases, you should create a colon definition that contains the sequence. A colon definition consists of a colon `:`, followed by the function name, followed by the sequence of COD functions that you wish to execute when the function name is typed, and terminated with a semi-colon `;`. For example, although there is no built-in COD function to square a number, you can create one with

```
COD> : X2 DUP * ;
```

which will have the effect of multiplying the top number on the stack by itself. After you have defined `X2`, it may be used in exactly the same way as any built-in function; thus,

```
COD> 3.0 X2
 9.0
```

A previously defined colon function may be used in the definition of a new colon function. An `X3` function, for example, can be constructed from the `X2` function with

```
COD> : X3 DUP X2 * ;
 9.0
COD> 3.0 X3
 9.0 27.0
```

The name of a colon function is not allowed to match the name of any built-in function or other colon function. Hence, a colon function cannot be used to redefine the action of any existing COD keyword.

It is possible to enter a multi-line colon definition interactively. While in the midst of a multi-line colon definition, the stack will not be printed just before the COD prompt. The following example shows one way to enter a colon definition that prints the integers from one to five:

```
COD> : COUNT5
COD>   5 1 FOR
COD>          I .
COD>       LOOP
COD> ;
 9.0 27.0
COD> COUNT5
 1.0
 2.0
 3.0
 4.0
 5.0
 9.0 27.0
```

The last line, just before the next COD prompt, is the stack. This allows us to verify that the original stack has been changed, and therefore, `COUNT5` is not altering the stack.

## 7.4 COD Files

COD provides a way to read commands from a disk file. These files contain the same commands that you would enter *via* the interactive mode. Commands not contained in a colon definition will execute as the file is read. In order to use a COD file as a model component in PLT, it is necessary that the file contain at least one colon definition and it is the last colon definition that will be called when the component is evaluated. As an example of a COD file, assume the file `LINE.COD` contains the following lines:

```
 ! COD program to calculate a line.
 ! P1 + P2*X
 : LINE  P1 X P2 * + ;
```

All lines that begin with '!' are considered comment lines and are ignored by COD. The third line contains the program itself. `P1` and `P2` refer to the parameters that will be adjusted to minimize $\chi^2$. When these words execute, they will load the value of the corresponding parameter into the stack. When writing COD programs that use parameters, you must use consecutive numbers starting with one — *i.e.*, do not leave any holes in the sequence. The keyword `X` is used to push the current value of $x$ into the stack.

It is also possible to use the COD program to read and test the code found in a COD file. The following example demonstrates how this can be done:

```
COD> GET LINE  ! Read the test file, note comment lines are echoed.
 ! COD program to calculate a line.
 ! P1 + P2*X
 NTERMS= 2
COD> NEW 1 2.  ! Set parameter 1 to 2.0

COD> NEW 2 1.  ! Set parameter 2 to 1.0

COD> 5         ! Place the number 5.0 in the stack
 5.0
COD> RUN       ! Run the program with an X value of 5.0
 7.0           ! The final result
```

The `RUN` command reads the top number on the stack, makes it the $x$ value, clears the stack, and then runs the last program in memory. All these steps ensure that COD is in the same state as it will be when called from the PLT routine.

The `Single` step command can be used to debug a COD function. In the above example, instead of typing `RUN`, you could have entered `Single Init`. This would have read the top number in the stack, made it the $x$ value, cleared the stack, and then executed the first step in the `LINE` colon definition. When using `Single` step, COD echos a line that contains three columns of information. The first column is the memory location that is about to be executed. The second column contains the encoded command which can be ignored. The third column is the decoded command that is to be executed. When taking single steps, the stack is still be printed just before the COD prompt appears. Hence, you can watch each step and its effect on the stack.

Code not contained in a colon definition will execute as the COD file is being read. Assume the `FUNC.COD` file contains the following lines:

```
 VAR 2PI
 2 PI * 2PI STO
 : FUNC X 2PI RCL * P1 / COS ;
```

While this file is being read, the variable `2PI` is created and loaded with the value of $2\pi$. The function `FUNC` can now access and use this variable.

## 7.5 Other Stack-Oriented Languages

People who have used the Forth, Postscript, and/or HP calculators will recognize certain similarities with COD. This is partly by accident, since all these languages were designed to solve the problem of making a very fast interpreted language. Given the similarity, it would be pointless for similar functions to be implemented differently in COD. Although there is no standard stack-oriented language, when compared to HP calculator language, and even to Postscript the deficiencies/limitations of Forth are serious. In addition, it is the author's opinion that more people know about HP calculators and Postscript, then about Forth. For these reasons, Forth will no longer be considered to be a model for COD. It is the intention of the current author to pattern new COD functions after existing functions from other languages. Currently, HP calculator language, as implemented on the HP48, is the most powerful such language and will be examined first for models of new COD functions.

# Appendix A

# COD Command Summary

## *

Multiply the top two numbers in the stack.

*Example:*

```
 5.0 2.0
COD> *
 10.0
```

## +

Add the top two numbers in the stack.

*Example:*

```
 5.0 2.0
COD> +
 7.0
```

## +LOOP

Terminate a COD `FOR` loop. When this statement executes, the number at the top of the stack is added to the current index. The loop terminates when the index passes the limit value. The `+LOOP` statement allows for loops in which the index value can either increase or decrease. This word can only be used in colon definitions.

*Example:*

```
COD> : TMP 0 2 FOR I . -1 +LOOP ;

COD> TMP
 2.0
 1.0
 0.0

COD> : DOUBLE 100 1 FOR I . I +LOOP ;
```

```
COD> DOUBLE
 1.0
 2.0
 4.0
 8.0
 16.0
 32.0
 64.0
```

## +STO

Add the previous number to the number stored at the address given at the top of the stack. Although it is easy to determine the address associated with a given variable, and hence use that address directly, it is advisable always to use a variable name to load an address into the stack before using `+STO`.

*Example:*

```
 0.0
COD> VAR TMP 5 TMP STO TMP RCL
 0.0 5.0
COD> TMP +STO
 0.0
COD> TMP RCL
 0.0 10.0
```

## –

Subtract the top two numbers in the stack.

*Example:*

```
 5.0 2.0
COD> -
 3.0
```

## .

Print the number at the top of the stack, and decrement stack pointer by one. The sequence "`DUP .`" can be inserted anywhere into COD functions to print the number at the top of the stack. This may help you figure out what the function is doing.

*Example:*

```
 1.0 2.0 3.0 4.0 5.0
COD> .
 5.0
 1.0 2.0 3.0 4.0
```

# /

Divide the previously entered number by the number on the top of the stack.

*Example:*

```
 5.0 2.0
COD> /
 2.5
```

# /MOD

Replace the top two numbers in the stack with the remainder and quotient of the previous number divided by the top number in the stack.

*Example:*

```
 23.1 10.0
COD> /MOD
 3.1  2.0
```

# 0<

Replace the top number in the stack with 1.0 if it is less than zero, 0.0 otherwise.

*Example:*

```
 -1.0
COD> 0<
 1.0
```

# 0=

Replace the top number in the stack with 1.0 if it equals zero, 0.0 otherwise.

*Example:*

```
 -1.0
COD> 0=
 0.0
```

# 0>

Replace the top number in the stack with 1.0 if it is greater than zero, 0.0 otherwise.

*Example:*

```
 -1.0
COD> 0>
 0.0
```

## 1+

Add one to the number at the top of the stack.

*Example:*

```
 3.0 5.0
COD> 1+
 3.0 6.0
```

## 1−

Subtract one from the number at the top of the stack.

*Example:*

```
 3.0 5.0
COD> 1-
 3.0 4.0
```

## 1/

Compute the inverse of the top number in the stack.

*Example:*

```
 5.0 2.0
COD> 1/
 5.0 0.50
```

## 2+

Add two to the number at the top of the stack.

*Example:*

```
 3.0 5.0
COD> 2+
 3.0 7.0
```

## 2−

Subtract two from the number at the top of the stack.

*Example:*

```
 3.0 5.0
COD> 2-
 3.0 3.0
```

## :

Begin a new colon definition. In COD, colon definitions define new dictionary words (*i.e.*, new functions). The token following the `:` is taken to be the name of the function. All words typed after the `:` are compiled (stored) into memory. A semicolon `;` terminates the colon definition and returns the state from compile to execute mode. The name of the function must not match any existing COD keyword. The interactive `COD` program does not print the stack when the internal state is compiling (*i.e.*, during a colon definition).

*Example:*

```
 0.0
COD> : X2 DUP * ;
 0.0
COD> 5
 0.0 5.0
COD> X2
 0.0 25.0
```

## ;

Terminate the current colon definition and return state from compile to execute mode. (See the `:` topic for an example.)

## <

Replace the top two numbers in the stack with 1.0 if the previous number is less than the top number, 0.0 otherwise.

*Example:*

```
 1.0 2.0
COD> <
 1.0
```

## =

Replace the top two numbers in the stack with 1.0 if the numbers are equal, 0.0 otherwise.

*Example:*

```
 1.0 2.0
COD> =
 0.0
```

## >

Replace the top two numbers in the stack with 1.0 if the previous number is greater than the top number, 0.0 otherwise.

*Example:*

```
 1.0 2.0
COD> >
 0.0
```

## ?

Display the number stored at the address given at the top of the stack. Although it is easy to determine the address associated with a given variable, and hence use that address directly, it is advisable always to use a variable name to load an address into the stack before using `?` .

*Example:*

```
 1.0 2.0
COD> VAR TMP 5 TMP STO
 1.0 2.0
COD> TMP ?
 5.0
 1.0 2.0
```

## ?Dup

Duplicate the number at the top of the stack only if it is non-zero.

*Examples:*

```
 5.0 0.0
COD> ?DUP
 5.0 0.0
COD> 1.0 ?DUP
 5.0 0.0 1.0 1.0
```

## A2tn

Compute the arctangent assuming the top two numbers in the stack represent an $x$,$y$ pair.

*Example:*

```
 1.0 2.0
COD> A2tn
 1.570796
```

## ABOrt

Reset the stack pointer. This deletes all numbers in the stack and can be very useful in the interactive mode to clean out the stack. If this command occurs when a COD function is executing, the function exits and a `NO` data function value is returned.

## ABS

Take the absolute value of the top number in the stack.

*Example:*

```
 5.0 -2.0
COD> ABS
 5.0 2.0
```

## ACos

Computer the arccosine (in radians) of the top number in the stack.

*Example:*

```
 5.0 0.5
COD> ACos
 5.0 1.047198
```

## ALog

Compute 10. raised to the power of the top number in the stack.

*Example:*

```
 5.0 2.0
COD> ALog
 5.0 100.0
```

## ASin

Compute the arcsine (in radians) of the top number in the stack.

*Example:*

```
 5.0 0.5
COD> ASin
 5.0 0.5235988
```

## ATan

Compute the arctangent (in radians) of the top number in the stack.

*Example:*

```
 5.0 0.5
COD> ATan
 5.0 0.4636476
```

## BEGIN

Begin a `BEGIN...UNTIL` or a `BEGIN...WHILE...REPEAT` structure. See either the `UNTIL` or `WHILE` topics for examples of use. This word can only be used in colon definitions.

## COS

Compute the cosine of the top number (in radians) in the stack.

*Example:*

```
 5.0 0.5
COD> COS
 5.0 0.8775826
```

## DDms

Convert a number in decimal degrees to the form DDDMMSS.S .

*Example:*

```
 12.5
COD> DDms
 123000.0
```

## DEPth

Leave the number of values contained in the stack (not counting the result).

*Example:*

```
 5.0 4.0
COD> DEP
 5.0 4.0 2.0
```

## DMsd

Convert a number of the form DDDMMSS.S to decimal degrees.

*Example:*

```
 123000.0
COD> DMsd
 12.5
```

## DRop

Drop the stack pointer so that the number at the top of the stack is lost.

*Example:*

```
 5.0 4.0
COD> DRop
 5.0
```

## DTor

Convert decimal degrees to radians.

*Example:*

```
 5.0 90.0
COD> DTor
 5.0 1.570796
```

## DUP

Duplicate the number on the top of the stack (equivalent to `1 PICK`).

*Example:*

```
 5.0 2.0
COD> DUP
 5.0 2.0 2.0
```

## ELSE

If the condition was false when the `IF` statement executed, then transfer control to the first statement following the `ELSE`. If the condition was true, then the function executes code down to the `ELSE` statement and then skips to the first statement following the `THEN` statement. This statement must be preceded by an `IF` statement. This word can only be used in colon definitions. (See the IF topic for an example.)

## EXIT

Immediately terminate the current colon function. Since the stack is unaffected, check to verify that the stack is left in the same state no matter how the colon function is terminated (otherwise obscure and nasty bugs result). This word can only be used in colon definitions.

## EXP

Compute the exponential of the top number in the stack.

*Example:*

```
 5.0 1.0
COD> EXP
 5.0 2.718282
```

## FOR

Set up a `FOR...LOOP` or a `FOR...+LOOP` structure using the top two numbers in the stack to denote the range. The index for the `FOR` loop is an `INTEGER*2`, hence the maximum value is 32767. This word can only be used in colon definitions.

*Example:*

```
COD> : TMP 4 1 FOR I . LOOP ;

COD> TMP
 1.0
 2.0
 3.0
 4.0
```

Warning to people who know Forth: The COD `FOR` statement is similar to the Forth `DO` statement; however, there is an important difference concerning the two numbers that precede the `FOR`. In COD, these represent the upper and lower index values respectfully; in Forth, the first number is one greater than the upper index value.

## HCos

Compute the hyperbolic cosine of the top number in the stack.

*Example:*

```
 5.0 0.5
COD> HCos
 5.0 1.127626
```

## HSin

Compute the hyperbolic sine of the top number in the stack.

*Example:*

```
 5.0 0.5
COD> HSin
 5.0 0.5210953
```

## HTan

Compute the hyperbolic tangent of the top number in the stack.

*Example:*

```
 5.0 0.5
COD> HTan
 5.0 0.4621172
```

## I

Push the index value of the innermost `FOR` loop onto the stack. This statement can only be used inside `FOR` loops inside a colon definition. (See the `FOR` topic for an example of use.)

## IF

If the condition is true, execute statements up to the corresponding `ELSE` or `THEN` statement. If the condition is false, pass control to the first statement following the `ELSE` if it exists, otherwise to the first statement following the `THEN`. `IF` structures can be nested. This word can only be used in colon definitions.

*Example:*

```
 X 1 <
 IF
  ! do these statements if X<1
 THEN

 X 1 >
 IF
  ! do these statements if X>1
 ELSE
  ! do these statements if X<=1
 THEN
```

## INT

Compute the integer portion of the top number in the stack.

*Example:*

```
 5.0 0.9
COD> INT
 5.0 0.0
```

## J

Push the index value of the next outer `FOR` loop onto the stack. This statement can only be used inside `FOR` loops inside a colon definition.

*Example:*

```
COD> : TMP 2 1 FOR
COD>           5 4 FOR
COD>               J . LOOP LOOP ;

COD> TMP
 1.0
 1.0
 2.0
 2.0
```

## LEAVE

Cause an immediate exit from the current loop. No statements from the `LEAVE` statement to the loop terminator are executed. This statement resembles the Fortran 8x EXIT statement. `LEAVE` can only be used inside `FOR` loops inside a colon definition.

## LN

Take the natural logarithm of the top number in the stack.

*Example:*

```
 5.0 2.0
COD> LN
 5.0 0.6931472
```

## LOG

Take the base-10 logarithm of the top number in the stack.

*Example:*

```
 5.0 2.0
COD> LOG
 5.0 0.3010300
```

## LOOP

Terminate a COD `FOR` loop. When this statement executes, one is added to the current index value. If the current index is less than or equal to the maximum index, then control is transferred to the first statement following the corresponding `FOR` statement. Otherwise, control passes to the statement following the `LOOP` statement. This word can only be used in colon definitions. (See the `FOR` topic for an example of use.)

## MAX

Replace the top two numbers in the stack with the maximum of the two numbers.

*Example:*

```
 1.0 3.0 5.0
COD> MAX
 1.0 5.0
```

## MIN

Replace the top two numbers in the stack with the minimum of the two numbers.

*Example:*

```
 1.0 3.0 5.0
COD> MIN
 1.0 3.0
```

## MOD

Compute the value of the previous number modulo the top number in the stack.

*Example:*

```
 2.0 3.0
COD> MOD
 2.0
COD> ABO 3.0 3.0
 3.0 3.0
COD> MOD
 0.0
```

## NEG

Negate the top number in the stack.

*Example:*

```
 5.0 2.0
COD> NEG
 5.0 -2.0
```

## NInt

Compute the nearest integer to the top number in the stack.

*Example:*

```
 5.0 0.9
COD> NInt
 5.0 1.0
```

## NOT

Replace the top number in the stack with 1.0 if it is zero, 0.0 otherwise.

*Example:*

```
 1.0
COD> NOT
 0.0
```

## OVer

Duplicate the second number on the stack (equivalent to `2 PICK`).

*Example:*

```
 5.0 4.0
COD> OVER
 5.0 4.0 5.0
```

## PI

Push the value of $\pi$ into the stack.

*Example:*

```
 5.0
COD> PI
 5.0 3.141593
```

## PICK

Duplicate the nth number on the stack (not counting n itself), where n is the top number on the stack. Note: `1 PICK` does the same thing as `DUP`, and `2 PICK` does the same thing as `OVER`.

*Example:*

```
 100. 200. 300. 400.
COD> 3 PICK
 100. 200. 300. 400. 200.
```

## RCL

Replace the address at the top of the stack with the number at that address. (See the `STO` topic for an example of how `RCL` is used.)

## REPEAT

Terminate a `BEGIN`...`WHILE`...`REPEAT` loop. When this statement executes, control is always passed to the first statement following the `BEGIN` statement. This word can only be used in colon definitions. (See the `WHILE` topic for an example of use.)

## ROLL

Rotate the nth number (not counting n itself) to the top of the stack, where n the top number in the stack. Note: `2 ROLL` does the same thing as `SWAP`, and `3 ROLL` does the same thing as `ROT`; and n must be greater than 1.0.

*Example:*

```
 100. 200. 300. 400.
COD> 4 ROLL
 200. 300. 400. 100.
```

## ROT

Rotate the third number to the top of the stack (equivalent to `3 ROLL`).

*Example:*

```
 100. 200. 300. 400.
COD> ROT
 100. 300. 400. 200.
```

## RTod

Convert radians to decimal degrees.

*Example:*

```
 5.0 1.0
COD> RTod
 5.0 57.29578
```

## SIN

Compute the sine of the top number (in radians) in the stack.

*Example:*

```
 5.0 0.5
COD> SIN
 5.0 0.4794255
```

## SQrt

Compute the square-root of the top number in the stack.

*Example:*

```
 5.0 2.0
COD> SQrt
 5.0 1.414214
```

## STO

Store the previous number at the address given at the top of the stack. Although it is easy to determine the address associated with a given variable, and hence use that address directly, it is advisable always to use a variable name to load an address into the stack before using `STO`.

*Example:*

```
 1.0
COD> VAR TMP
 1.0
COD> 5 TMP STO
 1.0
COD> TMP RCL
 1.0 5.0
```

## SWap

Swap the top two numbers on the stack (equivalent to `2 ROLL`).

*Example:*

```
 5.0 2.0
COD> SWap
 2.0 5.0
```

## TAN

Compute the tangent of the top number (in radians) in the stack.

*Example:*

```
 5.0 0.5
COD> TAN
 5.0 0.5463025
```

## THEN

Terminate an `IF` structure. This word can only be used in colon definitions. (See the `IF` topic for an example of use.)

## TSig

Transfer the sign of the top number in the stack to the absolute value of the previous number.

*Example:*

```
 2.0 -5.0
COD> TSig
 -2.0
```

# UNTIL

Terminate a `BEGIN`...`UNTIL` block. `UNTIL` pops one number off the stack. If that number is false (=0.0), the function jumps back to the first statement following the `BEGIN` statement. Otherwise execution continues with the statement following the `UNTIL` statement. This word can only be used in colon definitions.

*Example:*

```
COD> VAR Y                 ! Create variable Y

COD> : TEST 2 Y STO        ! Initialize Y to 2
COD> BEGIN
COD>   Y RCL .             ! Print the value of Y
COD>   Y RCL DUP * Y STO   ! Square it and store new value
COD>   Y RCL 1.E10 >       ! Test condition
COD> UNTIL ;

COD> TEST
 2.0
 4.0
 16.0
 256.0
 4.2949673E+9
```

# VAR

Define the following token to be a new variable name. The variable name is not allowed to match any existing COD keyword. When that variable is used in the future, it will cause the address of that variable to be loaded into the stack (for use with a following `STO` or `RCL` command).

*Example:*

```
 0.0
COD> VAR 2PI 2 PI * 2PI STO
 0.0
COD> 2PI RCL
 0.0 6.283185
```

# WHILE

The `WHILE` statement pops one number off the stack. If that number is true ($\neq 0.0$), the statement following the `WHILE` will be executed. If the number is false, then control passes to the first statement following the `REPEAT` statement. This statement can only be used inside a `BEGIN`...`WHILE`...`REPEAT` loop in a colon definition.

*Example:*

```
COD> VAR Y                  ! Create variable Y

COD> : TEST 2 Y STO         ! Initialize Y to 2
COD> BEGIN
COD>   Y RCL .              ! Print the value of Y
COD>   Y RCL 1.E10 < WHILE  ! Recall number and test for <1.E10
COD>   Y RCL DUP * Y STO    ! Square and store new value
COD> REPEAT ;

COD> TEST
 2.0
 4.0
 16.0
 256.0
 4.2949673E+9
 1.8446744E+19
```

## X

Push the current X value into the stack.

## ^

Raise the previously entered number to the power given by the top number in the stack.

*Example:*

```
 5.0 2.0
COD> ^
 25.0
```

# Appendix B

# PLT Command Summary

## CLear

`CLear`

Immediately clear the current plot device.

## COlor

`COlor [#] ON|OFf [glist]`

The first (optional) number allows you to reset the default color index for the plot groups specified in `[glist]`. If this number is omitted, then the default color index is not changed. `COlor OFf` turns off the plotting of all plot groups specified; `COlor ON` turns the plotting back on. If `[glist]` is omitted then all plot groups are affected.

`COlor MOdel #`

Plot the model using color index `#`.

`Color # ON Grid`

Use the color index specified by `#` when plotting the Grid in the currently active window.

`COlor ?`

Generate a list of possible color indices and their default color representations.

*Examples:*

```
PLT> COlor OFf 1,2,3  ! Suppress plotting of groups 1, 2, and 3
PLT> COlor ON  2      ! Turn on plotting of group 2
PLT> COlor 5 ON 3     ! Use color 5 when plotting group 3
```

## CONtour

```
CONtour [#] ?|COlor list|LEvel list|LStyle list|LWidth list|OFf
```

This command enables PLT to produce a contour plot. It is still experimental, and so the syntax could change. If PLT is displaying contours, then you can use the `SHow Contour` command to display the PLT commands that were used to generate that PLT.

## CQuit

```
CQuit
```

Immediately clear the plot device and exit subroutine PLT.

## CSize

```
CSize #
```

Set character size to `#` where `#` is greater than zero and less than five (one is default).

*Example:*

```
PLT> CSize 2.0       ! Use a character size twice the default
```

## Device

```
Device [$]
```

Change the current plotting device. The current plot device is released; the next plot will be produced on the new device. Note: `Device` with no argument releases the current plotting device.

*Examples:*

```
PLT> Device /PS      ! Output Postscript commands to a file
PLT> Plot            ! Send a plot to the file
PLT> Device          ! Close the file
```

## Error

```
Error OFf [glist]
```

Turn off the plotting of errors for all plot groups specified in `glist`.

```
Error ON  [glist]
```

Undo the effects of the `Error OFf` command for the specified plot groups.

```
Error Sq  [glist]
```

Set errors equal to `SQRT(value)` for the specified plot groups.

```
Error Dia [glist]
```

Draw diamond style errors on specified groups.

```
Error X ON|OFf [glist]
```

This command controls the plotting of the $x$-error bars. For example, if groups 1,2, and 3 all have associated errors, then `Xaxis 1`; `Error ON 2`; `Error OFf 3`, would cause the $x$-errors to be plotted when group 2 is plotted but not when group 3 is plotted.

In all of the above, `[glist]` can include `X` to specify the $x$-coordinate. When fitting data, error bars will be used to weight the data only if the errors are visible. Thus `Error OFf` followed by `Fit` will produce an unweighted fit. Also, note that only the $y$-errors are used to weight the data.

*Examples:*

```
PLT> Error OFf 1,2,3  ! Turn off errors for groups 1, 2, and 3
PLT> Error Dia 2      ! Plot diamond errors on plot group 2
PLT> Error ON         ! Plot errors for all plot groups
PLT> SKip Sing        ! Turn on the 'skip' mode
PLT> Error OFF X      ! Suppress plotting of errors on X-axis
```

## EXit

```
EXit
```

Exit subroutine PLT.

## Fit

```
Fit [#] [Iterate #]
```

Cause PLT to call the fitting routine to search for the best fitting parameters for the model specified with the `MOdel` command. The first optional number is the plot group to fit. If this number is omitted, then `Fit` will continue to fit the previous group that you were fitting if that plot group is still visible. For the first use of `Fit` or if the plot group has been `COlored OFf` then `Fit` will default to fitting the lowest numbered group which is visible. `LAbel PArm` command controls whether the model parameters are plotted on the right side of the plot. Fitting continues until $\Delta\chi^2$ is less than 0.05. As a default, you will be prompted to continue fitting every 10 iterations. If you wish to increase the number of iterations without being prompted, then use the `Fit Iterate [#]`. Thus, `Fit I 100`, would allow the program to try up to 100 iterations before you would be prompted again.

```
Fit ON [#]
```

Cause the current model to be plotted on group `#`. If `#` is omitted, the model will be plotted on plot group that was most recently fitted.

`Fit OFf`

Cause the model to no longer be plotted.

`Fit Plot #`

Control where the model is evaluated when it plotted. If `#` is greater than zero, then the model is evaluated at `#` points between the current $x$-scale Minimum and Maximum. If `#` is less than 0, then the model is evaluated at `ABS(#)` points between the Data Min and Data Max — *i.e.*, no extrapolation is allowed. If `#` equals 0, then the model is evaluated at the values of the data points. (This is the default.)

`Fit Stat Chi|Ml #`

Set the default fitting statistic to either $\chi^2$ or maximum likelihood. For example, `Fit Stat M 2` would vary the fit parameter to minimize the likelihood function when compared with plot group 2.

## FNy

`FNy #`

Return the value of the current `MOdel` function at location `#`.

*Example:*

```
PLT> MOdel LINR CONS ! Define a straight line
  1, LI: VAL( 1.00), SIG( 0.00 ), PLO( 0.00), PHI( 0.00)?
2.                   ! Set slope of line equal to 2
  2, CO: VAL( 1.00), SIG( 0.00 ), PLO( 0.00), PHI( 0.00)?
3.                   ! Set intercept of line equal to 3
PLT> FNY 3           ! Evaluate function at x=3.0
12.0                 ! The result
```

## FOnt

`FOnt $`

Set the default to the font specified by the character string. (Default is Simple font.)

`FOnt ?`

List possible fonts.

*Example:*

```
PLT> Font Roman      ! Use the Roman font
```

## FReeze

`FReeze [plist]`

Can only be used after a model has been defined. This command causes all parameters listed in `[plist]` to be frozen, which means the parameter value is not allowed to vary during a `Fit`.

*Examples:*

```
PLT> FReeze 2       ! Freeze the value of parameter 2
PLT> FReeze 3..5 9  ! Freeze the values of parameters 3 through 5 and 9
```

## GAp

`GAp #`

Control the size of the gap between the edge of the plot and the data extrema, when using the default scale. The effect of the `GAp` command can only be seen when you reset the default scale with `R`, `R X`, or `R Y` (all with no arguments). The default gap is 0.025 which will leave a 2.5 percent margin around the edge. The size of the gap in world coordinates, depends on whether the data are being plotted on a logarithmic scale. Therefore, if you wish to use a default scale with a logarithmic scale, you should first issue the `LOg` and `GAp` commands and then use the `Rescale` command to reset the default scale.

*Examples:*

```
PLT> GAp 0.0        ! No gap
PLT> R X            ! Use default X scale
PLT> GAp 0.05       ! Reset gap, for use with Y scale
PLT> LOg Y          ! Log the Y scale
PLT> R Y            ! Use default Y scale
```

## Grid

`Grid [clist]`

Control the plotting of a grid, where `[clist]` is one or more of `ON`, `OFf`, `X # #`, `Y # #`. For `Grid ON`, the major tic marks are expanded to place a grid over the entire plot. `Grid OFf` turns off the grid replacing the tic marks. PGPLOT automatically selects the location of the major and minor tic marks. The `Grid` command allows you to override this selection. For example, `Grid X 10,2` would divide the $x$-axis into 10 major divisions and then divide each major division into 2 minor divisions. Use `Grid X 0,0` to go back to the default grid. The number -1 can be used to suppress the plotting of tic marks. Thus, `Grid X -1 0` would only plot minor tic marks on the $x$-axis and `Grid Y -1 -1` would prevent any tic marks from being plotted on the $y$-axis.

IMPORTANT: PGPLOT only places major tic marks at locations where the least significant digit of the range increments by integer amounts. If you attempt to force PGPLOT to violate this condition, then unexpected things may happen. For example, suppose you had used `R Y 0 .15`, in which case the range is 0.15 and the least significant digit is 0.01. Then using `Grid Y 3,2` would place grid lines at intervals of 0.05. However, if you had tried `Grid Y 2,2`, then the grid lines would occur at intervals of 0.075, where the last digit (5) is not a significant digit. In this case, the plot will be incorrectly labeled. `Grid X 1.5,2` is legal and would correctly produce labels at intervals of 0.1. (Of course, only one label would actually be plotted in this case.)

## Hardcopy

`Hardcopy [$]`

Generate a copy of the plot using the current hardcopy specification. In general, this makes a file that can later be printed. The default PLT hardcopy device for the first use can be set using the PLT_HARDCOPY logical name (on VMS systems) or environment variable (on UNIX systems). After the first time, the `Hardcopy` command defaults to the same device as was specified in the previous `Hardcopy` command. `Hardcopy` produces a copy of what you would see if you reissued the `Plot` command. This might not be an exact copy of what is currently displayed on the graphics device.

`Hardcopy ?`

Display on the terminal the default hardcopy specification.

*Example:*

```
PLT> Hardcopy /PS   ! Create a Postscript file
```

## HElp

`HElp [pcommand]`

Get help on the PLT command specified by `[pcommand]`.

## Imodel

`Imodel # # [#]`

Integrate the current model over the range specified by the first two parameters. The third (optional) argument is the number of steps. (Default is 100.)

## LAbel

`LAbel X|Y|Top|OX|OY|OTop|File|G# [label]`

Place a label. The arguments `X`, `Y`, and `Top` would place a label on the $x$-axis, $y$-axis, or the top of the plot. It is possible to place an additional line of text just outside these locations by putting the letter '`O`' in front of these names. For example, `OT` would write a second label above the top label. Finally one can change the file name by using

`LA File [name]` If you should at any time wish to delete a label, then just omit the `[label]` from the command. The command `LA G# label` would associate a label with a particular plot group. PLT will use the group label on either the $x$ or $y$-axis if there is no corresponding $x$ or $y$ label.

`LAbel OFf`

Suppress plotting of all text labels. (This speeds up the production of the plot on slow devices.)

`LAbel ON`

Undo the effects of `LAbel OFf`.

`LAbel NX|NY ON|OFf [winlist]`

where `[winlist]` is a list of windows. NX affects the plotting of the numeric labels on the x-axis, NY on the $y$-axis. Thus `LAbel NX OFF 1`; `LAbel NY OFF 1`, will prevent the plotting of the numeric labels in both the X and Y directions for the first window. (Note, there are 32 numbered labels, so using `LAbel NX OF`, followed by several `LAbel #` commands will allow you to create labels consisting of text strings etc.

`LAb POS Y #`

Allows the position of the $y$ label(s) to be moved. The default position is `LA POS Y 2.0`.

`LAbel Rotate`

Rotate numerical labels plotted on the $y$-axis. The default PGPLOT mode is to plot the $y$-axis numerical labels in the vertical direction. `LAbel Rotate` will rotate these labels so they are written in a horizontal direction. If you issue the command a second time, then the labels will flip back to vertical in the next plot.

*Examples:*

```
PLT> LA F               ! Delete the file name from the plot
PLT> LA T Test! Plot    ! Top label is Test
PLT> LA T "Test! Plot"  ! Top label is Test! Plot
```

`LAbel Parm ON`

Display the parameter values associated with the current model, on the right side of the plot. (This is the default.)

`LAbel Parm OFf`

Suppress the display of the parameter values on the right side of the plot.

`LAbel # [clist] "string"`

Allow a label to be placed anywhere on the existing graph. Here `#` is a number in the range 1 to 32, `[clist]` is a list of subcommands that allow you to change various attributes of the label, and "string" is the (optional) text. For example,

```
PLT> LAbel 1 Pos 2 2 "test"
```

will create label 1 at position (2,2) containing the message `test`.

`LAbel # CEnter Top|Cap|Half|BAse|BOttom`

Control the vertical position of the text string. The default position is half, although the use of the `LIne` subcommand will override this.

`LAbel # COlor #`

Cause the label to be plotted with color index `#`. (Default is color index 1.)

`LAbel # CSize #`

Cause the label to be plotted with character size `#`. (Default is character size 1.0.)

`LAbel # Justify Left|Center|Right`

Control justification of text string. (Default is to center justify.)

`LAbel # LIne # [#]`

Draw line at angle `#` (in degrees) from position to the label. If the second number is specified, then it will be used as the length of the line in viewport units. (Default line length is 0.08.) If no number follows the `LIne` command, then the line is turned off.

`LAbel # LStyle #`

Control the line style of the line plotted, when the `LIne` subcommand is used. (Default is 1.)

`LAbel # Marker #`

Include marker `#` in the text line. The default will produce a left justified string just to the right of the marker. If you then right justify the string, then the string will appear to the left of the marker. In either case, the $(x, y)$ position corresponds to the position of the marker.

`LAbel # MSize #`

Use the specified marker size with plotting the specified numbered label.

`LAbel # Position # #`

Specify the $(x, y)$ location of the string in world coordinates. When using the `LIne` subcommand, `Position # #` gives the $(x, y)$ location of the position being 'pointed at' with the text string at the other end. If the `Marker` subcommand is used, then `# #` refers to the location of the marker. For other cases, `# #` is the location of the string. The `CEnter` and `Justify` subcommands can later override how text is plotted relative to a location. (The default location is (0,0).)

`LAbel # Position Cursor`

Display the cursor at the current default position. You can move the cursor to the desired position using the standard (PGPLOT) cursor keys. Once at the location where you want the label, press the space bar. The next time the plot is drawn, the label will appear at the new location.

`LAbel # Rotate #`

Plot the label at an angle of `#` (degrees) relative to the $x$-axis. (Default angle is 0.)

`LAbel # VPos # #`

Specify the $(x, y)$ location of the string in viewport coordinates. When using the `LIne` subcommand, `Position # #` gives the $(x, y)$ location of the position being 'pointed at' with the text string at the other end. If the `Marker` subcommand is used, then `# #` refers to the location of the marker. For other cases, `# #` is the location of the string. The `CEnter` and `Justify` subcommands can later override how text is plotted relative to a location.

`LAbel # VPos Curs`

Display the cursor at the current default position. You can move the cursor to the desired position using the standard (PGPLOT) cursor keys. Once at the location where you want the label, press the space bar. The next time the plot is drawn, the label will appear at the new location.

*Examples:*

```
PLT> LAbel 1 "TEST"   ! Place the word TEST at location (0,0)
PLT> LAbel 1 P 10 10  ! TEST will now appear centered at (10,10)
PLT> LAbel 1 LIne 90  ! Draw a vertical line from the point (10,10) to
                      ! the word TEST.
PLT> LAbel 1 CO 3     ! Color line and word TEST green
PLT> LAbel 1 P 10 10 LIne 90 CO 3 "TEST"   ! Does all the above in a
PLT>                                       ! single command
```

## LIne

`LIne ON [glist]`

Draw a line connecting all the points in each plot group specified in `[glist]`.

`LIne OFf [glist]`

Produce a scatter diagram by turning off the line for each plot group specified in `[glist]`.

`LIne Stepped [glist]`

Produce a stepped-line plot for each plot group specified in `[glist]`.

Note: If you set `Error OFf`, `MArker OFf`, and `LIne OFf`, then the line will still appear. The only way to prevent data from being plotted is to use the `COlor OFf` command.

*Examples:*

```
PLT> LIne ON          ! Use a line for all groups
PLT> LIne OFf 1,3     ! Turn off the line for groups 1 and 3
PLT> LIne Step 1,5    ! Plot groups 1 and 5 with a stepped line
```

## LOCation

`LOCation # [# [# [#]]]`

The `LOCation` command allows you to control the location of the currently active window. The default location of all windows is 0. 0. 1. 1. which means that all windows overlap and use the entire plotting surface. This command in combination with the `WIndow` command allows great control over where the windows are plotted. Thus a small window could be plotted inside a larger one. However, no attempt is made to erase a plotting region, so overlapping windows could result in overlapping text.

*Example:* To create 4 windows in the 4 quadrants, use:

```
PLT> WIndow 1
PLT> LOCation 0 .5 .5 1.
PLT> WIndow 2
PLT> LOCation .5 .5 1. 1.
PLT> WIndow 3
PLT> LOCation 0. 0. .5 .5
PLT> WIndow 4
PLT> LOCation .5 0. 1. .5
```

## LOg

`LOG X|Y|X,Y ON|OFf [winlist]`

Controls whether a log scale is used when plotting in the windows specified in winlist. Thus `LOG Y OFf 2 3 4`, would turn off the use of a log scale in the $y$ direction in windows 2 3 and 4. Also, `LOG X,Y OFf 3` would turn off the log scale in both the $x$ and $y$ directions when plotting in window 3.

## LStyle

`LStyle # [ON] [glist]`

Change the default line style for the plot groups specified in `[glist]`. The first number is the style type.

`LStyle # ON Grid`

Use the line style specified by `#` when plotting the grid in the currently active window.

`LStyle ?`

List possible line styles.

*Examples:*

```
PLT> LStyle 2 ON 3    ! Use line style 2 when plotting group 3
PLT> LStyle 1         ! Use solid line when plotting all groups
PLT> LStyle 5 ON 1,4  ! Use line style 5 when plotting groups 1 and 4
```

## LWidth

`LWidth #`

Set the line width to the value `#`. Allowed values are 1 or greater. On some laser printers, the default line width is very narrow and so, using thicker lines will enhance the output quality.

*Examples:*

```
PLT> LWidth 3         ! Triple the default thickness of all lines
PLT> HArd /PS         ! and make a hardcopy
```

## MArker

`MArker [#] ON [glist]`

Turn on the plotting of polymarkers. The first (optional) number is the marker type; if omitted the default marker type will not be changed. If `[glist]` is omitted, then markers will be used to plot all plot groups.

`MArker Size # ON [glist]`

Changes the size of the markers when plotting the plot groups specified in `[glist]`. The size can range from 0.0 to 5.0, where 1.0 is the default. Thus every plot group can have a different marker size.

`MArker OFf [glist]`

Turn off the plotting of markers for all plot groups specified. If `[glist]` is omitted, then markers will be removed from all groups.

`MArker ?`

Draw a table of all the PGPLOT markers on your current graphics device.

*Examples:*

```
PLT> MArk 19 ON 2      ! Use marker 19 when plotting group 2
PLT> MArk OFF 2        ! No longer plot group 2 with a marker
PLT> MArk ON 2         ! Use default marker when plotting group 2
PLT> MArk ON           ! Use markers when plotting all plot groups
PLT> MArk Size 5       ! Plot markers 5 times larger than default size
```

## MOdel

`MOdel ?`

List all built-in model components.

`MOdel @filename`

Cause the model definition and parameters to be read from the file with name `filename`.

`MOdel $`

Use to define models. Any combination of model components can be added together. For example, `MOdel CONS LINR QUAD` will add a constant term, a linear term, and a quadratic term.

For each parameter required by the `MOdel` command, you will be prompted for four numbers — `VAL`, `SIG`, `PLO`, and `PHI` — as described below. For each parameter, you should enter an initial value for `VAL`; but you can usually default on the other three numbers.

`VAL`: This is the actual value of the parameter. Although CURFIT will often find the the best set of parameters to model the data, it never hurts to start it with parameters near the expected best fit.

`SIG`: Any value of `SIG`≥0 will not affect the outcome of `Fit`. After you fit the model, `SIG` will contain the one-sigma curvature errors. This number is used by the `Uncertainty` command to start a formal error determination. If the `Uncertainty` command fails to converge because the original error estimate is wrong, sometimes you can help the convergence by adjusting `SIG` to be a better estimate before using `Uncertainty`. If you set `SIG`=-1, then the parameter is frozen such that CURFIT is not allowed to change the parameter value while fitting. If you set `SIG`=-IPAR, the next number (`PLO`) will default to 1, such that the current parameter value is forced to equal the value of parameter IPAR. (Note: IPAR can not equal 1 or the current parameter number.) If you place a number (N) after `SIG`, this will force the current parameter to be N times the specified parameter. (N defaults to 1.0.)

*Example:*

```
PLT> MOdel GAUS GAUS
  1, GC: VAL( 1.00), SIG( 0.00 ), PLO( 0.00), PHI( 0.00)?
,-4,2
  2, GW: VAL( 1.00), SIG( 0.00 ), PLO( 0.00), PHI( 0.00)?

  3, GN: VAL( 1.00), SIG( 0.00 ), PLO( 0.00), PHI( 0.00)?

  4, GC: VAL( 1.00), SIG( 0.00 ), PLO( 0.00), PHI( 0.00)?
3.
  5, GW: VAL( 1.00), SIG( 0.00 ), PLO( 0.00), PHI( 0.00)?

  6, GN: VAL( 1.00), SIG( 0.00 ), PLO( 0.00), PHI( 0.00)?
```

defines a model consisting of two gaussians, with the $x$ values of the centers differing by a factor of 2. Although you did not enter a value for parameter 1, it will be set to the value of 6 (2 times value of parameter 4). This relation will be maintained throughout a fit.

PLO, PHI: If SIG≥0 and if PLO<PHI, the parameter value is constrained to lie in the range PLO to PHI. Note: If PLO and PHI are both the same (say equal to zero), then the parameter will not be constrained in any way. In general, if you have difficulty fitting some data, the best thing to do is to freeze some parameters near to their expected values and then fit the reduced parameter set. When a good fit has been found with the reduced set, thaw some of the parameters and refit. If this method does not work, then you may be forced to use PLO and PHI to limit certain parameters to a meaningful range.

QDP/PLT currently supplies the model components defined below, which may be combined into multi-component models:

MOdel CONS

Select a model with a constant component:
FNY=FNY+CO.

MOdel LINR

Select a model with a linear component:
FNY=FNY+LI*X.

MOdel QUAD

Select a model with a quadratic component:
FNY=FNY+QU*X**2.

MOdel CUBI

Select a model with a cubic component:
FNY=FNY+CU*X**3.

MOdel X4

Select a model with an $x^4$ component:
FNY=FNY+X4*X**4.

MOdel X5

Select a model with an $x^5$ component:
FNY=FNY+X5*X**5.

MOdel POWR

Select a model with a power-law component:
FNY=FNY+PN*X**IN.

MOdel SIN

Select a model with a sinusoidal component:
FNY=FNY+SN*SIN(2*PI*(X-PH)/PE).

MOdel GAUS

Select a model with a gaussian component:
FNY=FNY+GN*EXP(-Z*Z/2.),
where Z=(X-GC)/GW and with integral SQRT(2*PI)*GN*GW.

MOdel EXP

Select a model with an exponential component:
FNY=FNY+EN*EXP(-(X-EC)/EW).

MOdel AEXP

Select a model with a symmetric exponential component ($e^{-|x|}$ for all $x$):
FNY=FNY+EN*EXP(-ABS(X-EC)/EW).

MOdel BURS

Select a model with a burst component (linear rise followed by an exponential decay):
FNY=FNY+0 for X<ST;
FNY=FNY+BN*(X-ST)/(PT-ST) for ST<X<PT; and
FNY=FNY+BN*EXP(-(X-PT)/DT) for PT<X.

MOdel SBUR

Select a model with a smooth-burst component:
`FNY=FNY+BN*(T**RR)*EXP(-(X-TS)/DT)`,
where `T=EXP(1)*(X-TS)/(RR*DT)`, such that `SBUR` = `BN` at the peak.

`MOdel PEAR`

Select a model with a Pearson-function component:
`FNY=FNY+K*(F1**M1)*(F2**M2)`,
where F1=[1.+(X-X0)/A1] and F2=[1.-(X-X0)*M1/(A1*M2)].

`MOdel WIND`

Select a model with a window-function component:
`FNY=FNY+LE` for T1<X<T2; and
`FNY=FNY+0` otherwise.

`MOdel KING`

Select a model with a King-profile component:
`FNY=FNY+S0*(1.+(X/RC)**2)**(-IN)`.

`MOdel LORE`

Select a model with a Lorentz-profile component:
`FNY=FNY+LN/(1.+[ 2.*(X-LC)/LW ]**2)`,
with integral `PI*LN*LW/2`.

`MOdel SPLN #`

Select a `#`-knot spline component.[1] The number of knots defaults to 2, which generates a straight line.

For unconstrained $y$ values, the natural spline condition is imposed, which sets $y'' = 0$ at the boundaries. You may not extrapolate this function outside the interval fitted.

It is possible to impose a periodic boundary condition on the spline curve. To do this, constrain the $y$ position of the last knot to be the same as the first. When this constraint is detected, the program automatically forces the first derivatives to match at the two boundaries. For this case, you are allowed to access the function outside the interval fitted. However, the function is assumed to be periodic, with the period given by the difference in $x$ between the first and last knots.

For example, `MOdel SPLN 5` will generate a 5-knot spline (10 parameters). The spline can be added to other models; thus `MOdel SPLN 5 GA` would add a 5-knot spline to a gaussian. Hence, the spline would model the 'background' and the gaussian, a 'line'.

[1] The spline is computed by solving equation 3.3.7 in the 1988 edition of *Numerical Recipes*, by Press, Flannery, Teukolsky, and Vetterling.

It is possible for the $x$ position of two knots to lie between two adjacent data points. This results in a local $\chi^2$ minimum as the lower knot adjusts to fit data below it, the upper knot adjusts to fit data above it. A strong wiggle occurs between the two knots but since there are no data points there, $\chi^2$ is not affected. In this section, two knots very close to each other will be called a collision. If collision occurs during a fit, then convergence will be very slow.

One method to greatly reduce the number of collisions is to first fit the $y$ locations before attempting to fit the $x$ locations. By default, the knots are evenly spaced in the $x$ direction and are not allowed to vary. For the first fit you should leave the $x$ positions frozen, although you can move the knots (using `Newpar`) to concentrate them where the function is changing rapidly. Once a reasonable set of $y$ positions is determined you can then thaw the $x$ positions and re-fit. You should never thaw the end points: They determine the range over which the spline is to be evaluated.

With the above recipe, collisions can still occur. The straight-forward method to separate the knots is: Use `Newpar` to re-position the two knots, freeze the $x$ locations, and then re-fit. After this the knots will sometimes stay separated when you thaw their positions and re-fit. The trick is to force the knots far enough apart so that they will not be attracted to the local minimum, but not so far apart as to grossly distort the fit.

Sometimes two knots collide when you are trying to fit the data with too few knots. This case can be easily tested for by increasing the number of knots and re-fitting.

`MOdel AKIM #`

Select a `#`-knot Akima component.[2] An Akima component is very similar to `SPLN` in that both use a cubic function to interpolate between the knots. Akima's method does not introduce false extrema and inflection points as does the cubic spline and therefore, is far superior for data that show abrupt transitions.

Like `SPLN` two different boundary conditions are allowed. If the last $y$ value is unconstrained, then the code uses 'virtual' knots outside the boundaries to determine the function at the boundaries. The locations of the virtual knots mirror the location of the knots just inside the boundaries. If the $y$ position of the last knot is constrained to match the $y$ position of the first knot then a periodic boundary condition is imposed.

`MOdel DEMO`

Call the Fortran user-defined component. Chapter 6 describes how to create how to write a Fortran function that can be linked in to PLT to replace the `DEMO` component.

`MOdel $codfile`

Call the user-defined COD (COmponent Definition) function found in `codfile.COD`. Briefly, a COD function is a program written in a Forth-like computer language. To understand COD, read the documentation or help file for COD. A COD file can be added to any combination of built-in components. For example, the model specified by

[2] Details of Akima's method can be found in "A new method of Interpolations and smooth curve fitting based on local procedures" by Hiroshi Akima in J. of the Ass. for Computing Machinery, (1970) 17, 589-602. (An implementation is described in PPC Journal, (1985) 12, no. 10, 11-14).

`MOdel CONS LINR $TEST` would calculate the sum of a constant term, a linear term, and the value of the COD function contained in the file `TEST.COD`.

At the present time only one COD function can be defined in a model, although this function can be referenced more than once. If you wish to combine two COD functions, you will need to write a third function that combines the first two.

COD should be used for all simple components that cannot be expressed by adding together the built-in components. Since a COD function is interpreted, it will run slower than the user-defined component. However, since COD is highly efficient and supports many mathematical functions, it is expected that the interpreter will be good enough for most purposes. For large numbers of points ($> 10^4$) or models that involve reading a disk file, the user is advised to write a Fortran function using the user component.

*Example:*

```
: GAUS ! The file must contain a : followed by a dummy name
X      ! Push current value of X onto the stack
X      ! Push current value of X onto the stack
*      ! Multiply the top two numbers on the stack to get X*X
P1     ! Push the value of parameter 1 onto the stack
*      ! Multiply to get P1*X*X
NEG    ! Negate the number on the top of the stack (-P1*X*X)
EXP    ! Calculate EXP of -P1*X*X
P2     ! Push the value of parameter 2 onto the stack
*      ! Multiply to get P2*EXP(-P1*X*X)
;      ! The function must end with a ; character
```

This simple COD function (`GAUS.COD`) contains two parameters and calculates the value of `P2*EXP(-P1*X*X)`. It could be written much more concisely as

```
: GAUS X X * P1 * NEG EXP P2 * ;
```

## Newpar

`Newpar`

Display the values associated with all of the parameters and allow the user to change them. If you wish to display the parameter values without changing them, then use the `WModel` command.

`Newpar #`

Display the values associated with the parameter specified by the first argument and allow the user to change them.

`Newpar # #`

Change the value of the specified parameter to the value you entered in the second (and following) arguments. You will not be shown the original values.

*Examples:*

```
PLT> Newp 2      ! Prompt for new values of parameter 2
  2, GW: VAL( 1.00), SIG( 0.00 ), PLO( 0.00), PHI( 0.00)?
3.               ! Value of parameter 2 is now set to 3
PLT> Newp 3 10   ! Value of parameter 3 is now set to 10
PLT> Newp 6,,-1  ! Freeze value of parameter 6
```

## Plot

`Plot`

Cause the plot to be redrawn on the graphics device.

`Plot All`

Cause all data points, including those flagged as no-data, to be plotted.

`Plot Good`

Undo the effects of the `Plot All` command and prevent plotting of points flagged as no-data (default).

`Plot Vertical`

Plot up to 20 plot groups in separate panels, in a vertical stack.

`Plot Overlay`

Plot all groups in a single panel (default).

`Plot Zero ON`

Cause the plot groups that have color index zero to be plotted with the background color. This is sometimes useful for erasing plots.

`Plot Zero OFf`

Do not plot groups with color index zero (default). This is much faster than plotting with the background color.

## PRompt

`PRompt $`

Redefine the “`PLT>`” prompt.

## Rescale

`Rescale X [#] [#]`

Reset XMIN and XMAX in the current window to the values specified. If both XMIN and XMAX are omitted, then PLT will reset the range to the default.

`Rescale Y [#] [#]`

Reset YMIN and YMAX in the current window to the values specified. If both YMIN and YMAX are omitted, then PLT will reset the range to the default.

`Rescale [#] [#] [#] [#]`

Reset XMIN, XMAX, YMIN, and YMAX in the current window to the values specified. If all four numbers are omitted, then PLT will reset both the $x$- and $y$-ranges to the defaults.

`Rescale ?`

Display the current XMIN, XMAX, YMIN, and YMAX values for each window.

Note: For Vertical plots each plot group can be specified separately; thus `R Y1` will rescale the $y$-range in window 1 and `R Y4` will rescale the $y$-range in window 4.

## SCr

`SCr # # # #`

Immediately change the color representation for the specified color index. The first number is the color index and the following three numbers give the red, green, and blue color intensities and must lie in the range 0.0 to 1.0. This command only works on color devices for which the color representation can be changed.

*Examples:*

```
PLT> SCR 0 1. 1. 1.  ! Set the background color to be white
PLT> SCR 1 0 0 0     ! Plot color index 1 in black
PLT> SCR 2 0 1 0     ! Plot color index 2 in green
```

## SHow

`SHow Contour`

Display on your terminal the PLT commands to generate the current contour plot (if any).

`SHow Group`

Display on your terminal information about each plot group.

`SHow Internal`

Display on your terminal the values of various PLT internal variables.

## SKip

Most PLT commands operate on 'groups' of data points. The default is for each vector of the input data to be in a separate group. For the default mode, commands like `COlor` and `MArker` affect the appearance of an entire vector. Using the `SKip` command, it is possible to independently control the appearance of sub-sets of data within a single vector. Thus, when using `SKip`, a single $y$ vector can be divided into several plot groups that can be independently controlled with `COlor`, `MArker`, `R Y1`, etc. Currently, `SKip` should only be used when the input data consists of two vectors as the other vectors will not be plotted. Note, `SKip` cannot affect whether a data point has an error associated with it.

```
SKip OFf
```

Each vector of the input data is plotted as a separate group (default).

```
SKip Single
```

A new plotting group begins every time $x$-coordinate equals `NO` (the no data flag) ONE or more consecutive times. `SKip Single` is useful when you wish to plot different groups with different markers.

```
SKip Double
```

A new plotting group begins every time $x$-coordinate equals `NO` (the no data flag) TWO or more consecutive times. `SKip Double` is useful when you wish to plot different groups using lines that may contain breaks.

*Example:* Consider the QDP file:

```
1  2
2  1
NO NO
3  4
4  3
NO NO
NO NO
5  6
6  5
```

With the default `SKip Off`, the above will be plotted as two groups each containing nine points. Using `SKip Single`, would cause the above data to be divided into three groups. The first group would consist of the data in the first three lines, the second would come from lines four to seven, and the third group from lines eight and nine. Using `Skip Double` would cause the above data to be plotted as two groups with lines one through seven being in the first group and the last two lines making the second group.

## STatistics

```
STatistics [fgroup]
```

where [fgroup] is the default group for fitting. This command causes a short table to be printed on your terminal that displays some basic statistical properties about that group of data. The first line tells you which group is fitted and over what range. Next the unweighted average, variance, and 3rd moment are displayed. For the unweighted data, the column labeled SUMW contains the total number of points used in the calculation, for weighted data, SUMW is the sum of the weights. YMIN and YMAX are the minimum and maximum data values in the range. If the plot group has errors associated with it, then weighted values of the average, variance, and 3rd moment will be displayed. The next row contains WCHI and WRED which are the $\chi^2$ and reduced $\chi^2$. The W is appended to remind you that the actual errors on the data were used. The line labeled Sum of Y*XDEL contains the sum of the y values times the $\Delta x$ values, where $\Delta x$ is given by the $x$-error bars. This is a rectangle rule integral of the data. The last line gives the (unweighted) linear correlation coefficient of the $y$ vs. $x$ data.

For maximum accuracy, this routine makes two passes through the data, once to calculate the average, and the second time to calculate moments based on the difference between the data and the average.

If you don't understand the difference between the unweighted and weighted values then you should use unweighted quantities.

*Example:*

```
PLT> STat
Group  2, from   430.0    , to   540.0

        YBAR        YVAR        Y3M         SUMW       YMIN         YMAX
UNWTD  0.5915      0.1341     -8.3771E-03   23.00     2.2100E-02   1.096
  WTD  7.8728E-02  2.0009E-02  1.2435E-02  4.9056E+05
 WCHI=  9.389E+03,  WRED=  426.768

     Sum of Y*XDEL=   0.883411
Correlation coeff.=  -0.853596
```

## THaw

```
THaw [plist]
```

Can only be used after a model has been defined. This command causes all parameters listed in [plist] to be thawed, which means the parameter value will be allowed to vary when fitting.

*Examples:*

```
PLT> THaw 2         ! Cause parameter 2 to be thawed
PLT> THaw 3..5 9    ! Cause parameters 3 through 5 and 9 to be thawed
```

## Time

```
Time ON
```

Cause the date and time to be plotted in the lower right corner (default).

```
Time OFf
```

Remove the date and time from future plots.

## Uncertain

```
Uncertain [# [# [#]]]
```

Vary the specified parameter(s) in order to estimate their uncertainties. Each specified parameter, in turn, is stepped and $\chi^2$ is minimized. Stepping stops when the requested value of $\Delta\chi^2$ is obtained. `Uncertain` can take up to 3 numbers as arguments. If one number contains a decimal point, then that number is interpreted as the requested value of $\Delta\chi^2$ (which for the first time defaults to 2.7 and for later times defaults to the previous value). The remaining two numbers in the `Uncertain` command specify the lower and upper parameter numbers for which you want to estimate the error. If only one number is given (without a decimal point), then the error is generated only for a single parameter. If errors are currently turned off (or do not exist), then the routine works out a correction factor that converts the W-VAR to $\chi^2$.

## UPper

```
UPper # ON [glist]
```

If a number in one of the groups specified in glist is less than `#` sigma from zero, then plot that number as a `#`-sigma upper limit.

*Example:*

```
PLT> UPper 2.7 ON 3   ! When plotting group 3, all numbers within 2.7
PLT>                  ! sigma of zero will be plotted as an upper limit.
```

## VErsion

```
VErsion
```

Return the date of last modification to the current version of PLT.

## Viewport

```
Viewport  #,[#,[#,#]]
```

Control location of the viewport in normalized device coordinates, where (0.0,0.0) is the bottom left corner and (1.0,1.0) the top right corner. The default viewport is 0.1 0.1 0.9 0.9, with the first two numbers giving the location of the bottom left corner and the next two numbers, the upper right corner. If you use `Viewport` with and only specify two numbers then PLT centers the viewport about the center of the plot, thus `View x,y` is the same as `View x,y,1.0-x,1.0-y`. If you do not wish to center the viewport, then you can specify all four numbers, where the last two numbers refer to the top right corner.

*Examples:*

```
PLT> View .4 .4         ! Viewport extends from (.4,.4) to (.6,.6)
PLT> View .8 .8 .9 .9   ! Use small viewport in top right corner
PLT> View .1 .1         ! Go back to the default viewport
```

## WData

```
WData [$]
```

Write all data between the current $x$-scale minimum and maximum to a QDP file. If you want all the data to be written to the file then you should use the `R X` command to reset current scale to include the minimum and maximum data values. A blank file name will cause the data to be written to your current terminal screen.

The `WData` command will not write any PLT commands to the file. However, it will include a reference to an indirect file. For example, `WData TEST` will create a file called `TEST.QDP` that includes the line `@TEST`. The PLT command `WHead` can be used to create a `TEST.PCO` file that contains all the PLT commands needed to re-create the current plot.

```
WData [$] #
```

Write the data with only `#` digits of accuracy (numbers will be rounded). If `#` is negative, the error on a number is written out to (-`#`) number of digits and the number itself is written to the same accuracy.

*Examples:*

```
PLT> WData           ! Write the data to the terminal screen
PLT> WData TEST      ! Write the data to TEST.QDP
PLT> WData TEST 3    ! Write the data (3 significant digits) to TEST.QDP
PLT> WData TEST -2   ! E.g., 123.758 +/- 2.698 will be written 123.8 2.7
PLT> WData,,-2       ! As above, but written to the terminal screen.
```

## WEnviron

`WEnviron [$]`

This command does the same thing as if you entered a `WHead` command followed by a `WData` command. This command should be used if you want to save both the current data and the PLT commands needed to re-create the current plot.

*Examples:*

```
PLT> WEnv          ! Write commands and data to the terminal screen
PLT> WEnv TEST     ! Create TEST.PCO and TEST.QDP files
PLT> WEnv TEST 3   ! Write the data (3 significant digits) to TEST.QDP
PLT> WEnv TEST -2  ! E.g., 123.758 +/- 2.698 will be written 123.8 2.7
PLT> WEnv,,-2      ! As above, but written to the terminal screen.
```

## WHead

`WHead [$]`

This command only writes the list of PLT commands needed to create the current figure. Since this command will NOT write any data, it will run faster than the `WEnviron` command. Typically one would first use `WEnviron` to write both the PLT commands and the data to files. If any changes are made to the appearance of the plot (such as adding labels, etc.) then the `WHead` command can be used to update the PLT command file without over-writing the QDP file containing the data.

*Examples:*

```
PLT> WHead          ! Write commands to the terminal screen
PLT> WHead TEST     ! Write commands to TEST.PCO
PLT> WHead TEST 3   ! Same as previous (the 3 is ignored)
```

## WIndow

`WIndow #`

This command sets the currently active window to be the number specified by `#`. After the window command has been issued, commands like `Rescale X`, `LA Y` will affect the currently active window. For maximum compatibility, a `Plot Vertical` command creates N windows numbered by the number of the plot group that they contain. Thus if group 1 is used on the x-axis, then the upper (first) window plotted will contain plot group 2 and will be plotted in window 2.

## WModel

`WModel [$]`

Write the current model into the named file. The model written out can later be read with the `MOdel @filename` command. If you do not enter a file name, the model will be written to your terminal screen. Since all significant digits are written, writing a file provides a good way to save your current `MOdel` parameters. If you have previously `Fit` the data then this command will write two additional lines at the end of the model file as comments. These lines are the WVAR and NBIN obtained in the most recent fit.

## Xaxis

`Xaxis #`

Causes the plot group `#` to be used as the $x$ variable. Thus `Xaxis 3` will cause plot groups 1,2 (and any >3) to be plotted as a function of group 3. A `LAbel Y3` command will associate a label with the third plot group and will then appear as the $x$-axis label.

`Xaxis Linear # #`

Cause the $x$ variable to be a linear function. Thus, the command `Xaxis Linear 10. 1` would cause the first point to be plotted at $x$=10, the second point at $x$=11, the third at $x$=12, etc.

## Yaxis

`Yaxis [ON] [glist]`

where `[glist]` is a list of plot groups. This command is more intuitive to naive users than the `COlor ON` command. This command causes the plot groups specified in `[glist]` to turned on (plotted) in the currently active window.

`Yaxis Lin # #`

Specify the $y$-axis scale to be used for contour plots.

*Example:* Assume you have a 10 by 10 array of data, then the commands then

```
PLT> Xax L 10 1  ! Would cause the X values to range from 10 to 19
PLT> Yax L 5 1   ! Would cause the Y values to range from 5 to 14
PLT> CON Lev 1,2,3 ! Draws a contour plot with these scales
```

## $

`$ [command]`

Spawn to the operating system, where `[command]` is an operating system command. If no command is specified, then a system shell is created that will allow you to enter several commands until you logout (under VMS) or exit (under UNIX or DOS).

*Examples:*

```
PLT> $       ! Spawn to system (assume VMS)
Spawning...  ! Wait for something to happen
$ (enter VMS commands)
$ LO
PLT>         ! You have now returned to PLT
PLT> $ DIR   ! This will display your current directory
Spawning...  ! Wait for something to happen
(directory appears here)
PLT>         ! and you are left in PLT.
```

## @

`@ $`

Execute commands from an indirect command file. Command files can be nested to a depth of 10. The default file type is `.PCO` (for Plt COmmands).

*Example:*

```
PLT> @NICE   ! Execute the PLT commands in the file NICE.PCO
```

# Appendix C

# QDP Command Summary

QDP commands must be inserted at the beginning of a QDP file, as these commands tell QDP how to read in the data. Any command not recognized by QDP is passed to PLT. QDP separates command lines from data lines based on the first non-blank character in the line. If this character is `+` , `-` , `.` , or a digit, then the entire line will be read as data.

## READ Serr

`READ Serr [vlist]`

Tell QDP/PLT which vectors have symmetric errors. The command `READ Serr 1 3 5` will cause vectors 1, 3, and 5 to be read with symmetric errors, and vectors 2 and 4 to be read without. Only one `READ Serr` command should appear in a QDP file.

*Example:*

```
READ Serr 1 3 5
 1. .1     2.    3. .3    4.   5. .5
```

This would be read as 5 vectors: $1.0 \pm 0.1$, 2.0 (no error), $3.0 \pm 0.3$, 4.0 (no error), and $5.0 \pm 0.5$. Without the `READ Serr` command, it would be read as 8 vectors.

## READ Terr

`READ Terr [vlist]`

Tell QDP/PLT which vectors have two-sided errors. It takes three columns to specify a vector with two-sided errors. The first column is the central value, the second column (which must be positive) specifies the upper bound, and the third column (which must be negative or zero) specifies the lower bound.

*Example:*

```
READ Serr 1
READ Terr 2
 1. .1    2. +.1 -.2
```

This would be read as $1.0 \pm 0.1$ and $2.0^{+0.1}_{-0.2}$. Note: In fitting, non-positive errors are ignored; thus the first error of two-sided errors should be positive.

# Appendix D

# Installation Guide

## D.1 XANADU

The QDP/PLT software is a stand alone segment of a larger package called *XANADU* (*X-ray ANalysis And Data Utilization*). Subroutines commonly used in XANADU software are placed in a library/archive called XANLIB. QDP/PLT is supplied with source code for the entire XANLIB library. If you are short on disk space, it is possible to delete many of the supplied files. This appendix describes the minimum set of source files you need from these directories. Of course, if you don't plan to modify the code you can delete all source files once the object library has been created.

All XANADU software uses a virtual disk called `XANADU` to hide system dependent disk names. It is possible to run the QDP/PLT software without implementing the virtual disk, however, some commands such as interactive help will not be able to locate supporting files.

## D.2 VMS Instructions

All the QDP/PLT software can be used by adding a few lines to your `LOGIN.COM` file. First, you must define the `XANADU` logical name (to create a virtual disk). In brief, if QDP is in the directory called `DRB1:[XRAY.BIN]`, then the following line should be in your `LOGIN.COM`:

```
$ DEFINE/TRANS=(TERM,CONCEAL)   XANADU   DRB1:[XRAY.]
```

(The above line is *very* system dependent.) In this example, `DRB1:` is the physical device name. If you do not translate to the physical device name, but to a logical name (for example, `USER:[XRAY.]`) then you should omit the `TERM` option for the `/TRANS` switch. You will need to define the the following logical names:

```
$ DEFINE   GRAPHICS   XANADU:[PLOT.PGPLOT]
$ DEFINE   GRPSHR     GRAPHICS:GRPSHR.EXE
$ DEFINE   PLT$FONT   GRAPHICS:GRFONT.DAT
$ DEFINE   UFNYSHR    XANADU:[LIB]UFNYSHR.EXE
```

`GRAPHICS` should point to the top level PGPLOT directory. In the above example, this was assumed to be `XANADU:[PLOT.PGPLOT]` and should be changed appropriately if

PGPLOT lies in another location. GRPSHR and PLT$FONT should not need to be changed. You will also need to setup symbols pointing to both QDP and COD with

```
$ QDP       :==$ XANADU:[BIN]QDP
$ COD       :==$ XANADU:[BIN]COD
```

## D.3 SUN UNIX Instructions

In order to create a *virtual* disk on a Unix system, it is necessary to create a link in the root directory. To do this, you must be root on your machine. If QDP is in the directory /user/xray/bin, then go to / and type

```
% ln -s /user/xray xanadu
```

In your .cshrc file, you will need to define the the following PGPLOT environment variable:

```
setenv PGPLOT_FONT /xanadu/plot/pgplot/grfont.dat
```

Finally you will need to include the XANADU bin directory in your current path. If you have not already added other directories to your upath, you should add the following line to your .cshrc file:

```
set upath = (/xanadu/bin)
```

## D.4 NeXT NeXTStep Instructions

The UNIX interface on the NeXT is highly compatible with the SUN. Therefore you should follow the instructions given in the previous section. Currently, QDP must be run from within a terminal application and not as a standalone program with its own icon.

## D.5 MS DOS Instructions

PGPLOT and QDP/PLT have been tested under MS DOS. Currently the only PGPLOT device handler that supports IBM graphics cards (EGA and whatnot) requires the use of Microsoft Fortran 5.0 (or later). If you do not have this version of Microsoft Fortran, you will need to write a new device handler as described in the PGPLOT manual. DOS versions of the system dependent routines exist, and all the of the QDP/PLT software has been compiled and tested with the Microsoft Fortran compiler. Command line editing is fully implemented under DOS, but you will need to install the DOS ANSI.SYS device driver. This is done by adding a line like the following to your CONFIG.SYS file.

```
Device   = C:\ANSI.SYS
```

To default with command line editing switched on you should add the following line to your AUTOEXEC.BAT file.

```
SET GTBUF_EDIT=ON
```

## D.6 Portability

The QDP/PLT software was originally developed on a DEC-VMS system and later ported to a SUN-UNIX and NeXT NeXTStep systems. QDP/PLT is currently supported on these three systems. Since standard Fortran is extremely portable, it should be a simple matter to port QDP/PLT to other systems. Support for other systems will be minimal (due to lack of time), but occasionally QDP/PLT will be tested on other systems, such as MS DOS, to ensure that major problems are not being introduced.

The author is interested in any attempt to port the QDP/PLT software to other systems and should be consulted before any such attempt is made. System dependent routines have been isolated into two files called `SYSIO.xxx` and `SYS.xxx`, where `xxx` denotes the operating system. If the software is ported to new systems, it may be necessary to add additional routines to the `SYS.xxx` file. Although `SYS.xxx` should only be used on one system, you should still write the routines in standard Fortran so that others can use your file as a template.

## D.7 Relation to PGPLOT

The QDP/PLT software can be considered to be a layer on top of PGPLOT. Thus when installing QDP/PLT on your system, you must first get PGPLOT working. PGPLOT can either be obtained directly from Tim Pearson or from the author when you obtain the QDP/PLT software. If you are already running PGPLOT on your system, then you will need to check that the installed version is sufficiently recent to work with QDP/PLT. If your version of PGPLOT does not contain the routines PGBBUF/PGEBUF, then you will need to update it. You may still wish to update PGPLOT if you discover that your version is older than the version currently being used with QDP/PLT. Of course, if you decide to update your version of PGPLOT, you should be careful to save any locally written or modified versions of PGPLOT device drivers.

If you are not running PGPLOT on your system, then you will need to install it. Since PGPLOT uses its own set of logical names to locate supporting files, it can be located anywhere. However, for consistency with other XANADU systems, you may wish to install PGPLOT in the `XANADU:[PLOT.PGPLOT...]` directory.

## D.8 Directory Structure

In this documentation, VMS file names have been used. It is a simple matter to map VMS file names to UNIX or DOS names. A file name of `XANADU:[LIB.PLT]PLT.FOR` implies that the file `PLT.FOR` is on the `XANADU` disk, in the `PLT` sub-directory of a main directory called `LIB`. For example, on a Unix system, the above file would be called `/xanadu/lib/plt/plt.for`. For ease of sharing XANADU files with systems that are not case sensitive, only lower case file names are allowed under Unix. On an MS-DOS system, `XANADU` should be the top level directory on your default hard disk; so our sample file would be called `\XANADU\LIB\PLT\PLT.FOR`. An attempt should be made to preserve this type of organization on other systems.

The following directories of the `XANADU` virtual disk contain files needed by the QDP/PLT software:

`XANADU:[BIN]` contains the executable versions of both COD and QDP.

`XANADU:[LIB]` contains the XANLIB object library.

`XANADU:[LIB.COD]` contains a set of sample COD files.

`XANADU:[LIB.PLT]` contains the source code for the PLT subroutine and for other supporting routines.

`XANADU:[LIB.TERMIO]` contains the source code for the low level terminal IO routines.

`XANADU:[LIB.UFNY]` contains the source code for the demo user function. On VMS systems `UFNY.FOR` should NOT be installed into the XANLIB library, but rather the sharable library used instead.

`XANADU:[LIB.XANLIB]` contains the system dependent routines. Currently, there is a `SYS.VMS` should be used on VAX VMS systems, `SYS.SUN` on SUN UNIX systems, and `SYS.NEX` on NeXT NeXTStep systems.

`XANADU:[LIB.XCOMS]` This directory contains the system-wide indirect command files. For example, the file `HARD.PCO` should create a hardcopy file and then queue the file to the printer.

`XANADU:[LIB.XHELP]` contains the source code for the interactive help.

`XANADU:[LIB.XPARSE]` contains the XSPEC parser routines. Currently the following files are required from this directory: `IXPLWR.FOR`, `XCHKBL.FOR`, `XCHKDL.FOR`, `XCHOSE.FOR`, `XCREAD.FOR`, `XGTARG.FOR`, `XMATCH.FOR`, `XQMTCH.FOR`, `XQUEST.FOR`, `XSQUEZ.FOR`, `XUNIDS.FOR`, and the include file `XPARINC.INC`.

`XANADU:[PLOT.QDP]` contains the source code for the COD and QDP programs, the interactive help files, and the demonstration QDP files.

`XANADU:[PLOT.QDP.MANUAL]` contains the source listings of this manual in LaTeX format. To print the manual, you will need to issue the command `LATEX QDP` twice, to ensure that the table of contents is correct.

`XANADU:[SRC.DOC]` contains the source code for the system level help programs. These are not needed to run the QDP/PLT software, but are useful when creating the help libraries.

## D.9 Porting to other systems

When porting QDP/PLT to a new system, you should first get the PGPLOT software working. There are extensive instructions in the PGPLOT manual to help you in this area. Once PGPLOT is working you should next direct your attention to the TERMIO software.

### D.9.1 Porting TERMIO software

The TERMIO routines provide the basic terminal I/O for XANADU. Currently the TERMIO software reads and writes to the terminal using one of two completely different methods. One method involves standard Fortran I/O and the second method involves single-character I/O. The single-character method supports command line editing, which should be regarded as a convenience and not as a necessity. Therefore when porting TERMIO to a new operating system, it is a good idea to first get the code working without command line editing. Once the code is working and you have some free time, then you can go back and add the single character I/O routines.

The system dependent routines are in `SYSIO.xxx`. Initially `SYSIO.xxx` should be fairly simple and only allow standard Fortran I/O. To disable single character I/O, you will need to create a new version of `SYSIO.xxx` (where xxx is your system descriptor). This file should contain six routines, and five of these routines can return without doing anything. The routine `FORTYP` should return with the variable `IFTYPE` set equal to zero. When this is done, it becomes impossible to accidently turn on command line editing, which would cause the program to go into an infinite loop if the `RDCHR` and `PUTSTR` routines have not been implemented.

The `[LIB.TERMIO]` directory contains several `makefile`'s, plus an example program `TSTREC.FOR`. You should try out the TSTREC program on your system to ensure that the basic terminal I/O routines are working.

Once you have the standard Fortran version working, and are fishing around for something to do, you should then implement the single character I/O routines. This means implementing the other routines found in `SYSIO.FOR`. Since many UNIX systems do not allow system functions to be called directly from Fortran, many systems use some C code to provide this interface. Under SUN UNIX some routines are implemented using the file `ciosun.c`. The `SYSIO.FOR` routine `TTINIT` should put the terminal into single character I/O mode (called cbreak in UNIX). `TTRSET` should return the terminal to normal mode (called cooked in UNIX). `RDCHR` should read a single character, and `PUTSTR` should write a string to the terminal. Both `RDCHR` and `PUTSTR` should work in passthru mode where control characters (such as escape) are not interpreted by the terminal driver but rather passed to the terminal. `PUTSTR` can buffer the output, until `FLUSH` is called, whereon all data should actually be written to the terminal. Finally, you will need to modify `FORTYP` to return either +1 or -1 depending on whether Fortran on your system outputs a return before or after each Fortran `WRITE` operation. This will also allow command line editing to be switched on.

To test command-line editing, try the `TSTREC.FOR` program and use the interactive `%ED%ON` command to switch it on. Once you are convinced that command-line editing is working you can then use the GTBUF_EDIT logical name/environment variable to automatically switch on editing for all XANADU software.

### D.9.2 Creating a new SYS.xxx routine

Before you can run QDP you will need to create one other system dependent file called `XANADU:[LIB.XANLIB]SYS.xxx`. As described below, not all routines in `SYS.xxx` need to be fully implemented in order to use QDP/PLT. In addition, some of the routines are used by other parts of the XANADU software and are not needed by QDP/PLT This section only deals with the routines that are needed by QDP/PLT.

The following routines are implemented in standard Fortran in `SYS.SUN` and therefore you should be able use that version without modification:

```
FRELUN   Free up a logical unit number
GETLUN   Get a free logical unit number
LOCASE   Convert to lower case
UPC      Convert to upper case
```

The following routines can be considered optional in that QDP/PLT will still work if these routines do nothing. Of course, implementing these routines will increase the usefulness of QDP/PLT.

```
CONC     Converts filename to system preferred case
PLTTER   Toggle graphics/alpha mode on terminal
RDFORN   Read a foreign command, i.e., the command line
SPAWN    Spawn to the operating system
```

The last set of routines need to be implemented, although in many cases some loss of functionality is allowed. For example, subroutine `PROMT` must display the prompt. It would be nice if the cursor was left at the end of the prompt line, but if you don't know how to do that on your system, use a standard Fortran write operation.

```
DIRPOS   Return the number of characters in directory spec
OPENWR   Wrapup for the Fortran OPEN statement
PROMPT   Write a prompt on the user's terminal
PTEND    Add prefix (disk and directory name) to file names
TRLOG    Translate logical name/environment variable
```

### D.9.3 Compile and link the QDP program

The final step should be fairly simple. You should compile all the programs in the `[LIB.PLT]` and `[LIB.XHELP]` directories. You should also compile the needed files from `[LIB.XPARSE]` and `[LIB.UFNY]`. The non system dependent routines should all compile without errors. If you do get an error (for example, due to some non-standard Fortran sneaking in) then please let the author know so the original can be made made more portable. All files in the `[LIB...]` directory tree should be placed in a library/archive. Finally you should move to the `[PLOT.QDP]` directory and try to link the QDP program. There are several `makefile`'s that can be used as examples.

# Appendix E

# Sample Plots and QDP Files

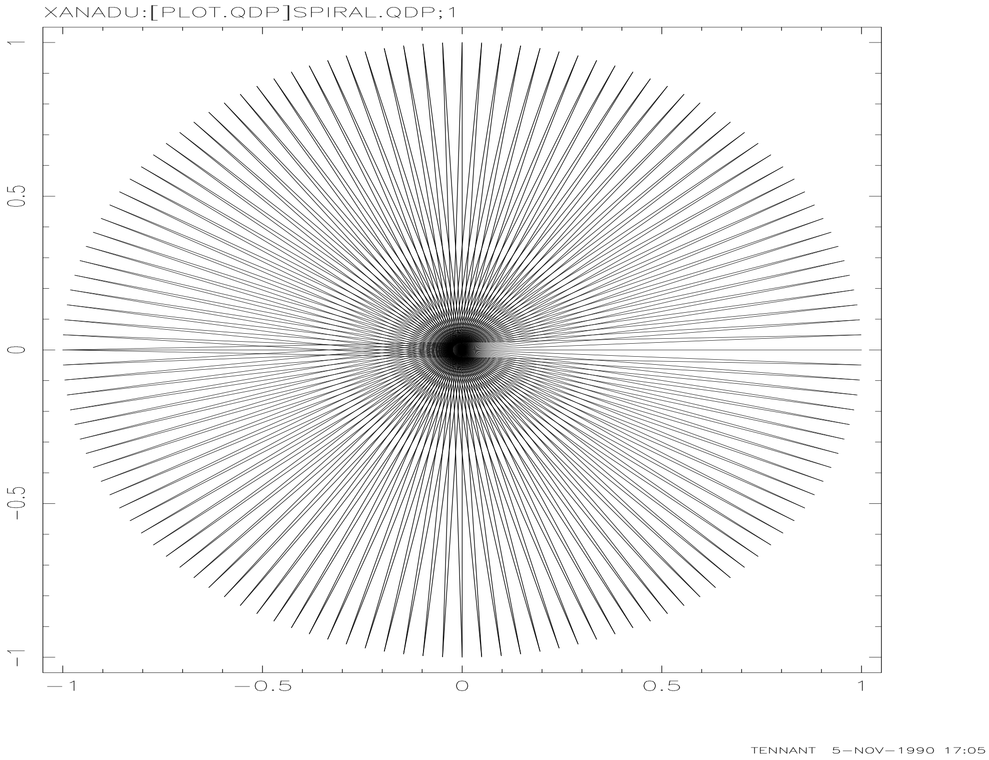
This appendix contains several sample figures that were created with the QDP program. In all the figures, the name of the QDP file used to generate the figure is displayed in the top left corner. For the first figure this name is `XANADU:[PLOT.QDP]SPIRAL.QDP`. It is possible to reproduce this figure by using:

```
$ QDP XANADU:[PLOT.QDP]SPIRAL
```

For reader convenience, the top section of each QDP file is listed. In cases where the QDP also uses a PLT command file, the top section of the `.PCO` file is also listed. A careful comparison of each figure and the PLT commands used to generate it, will illustrate the actions of many PLT commands.

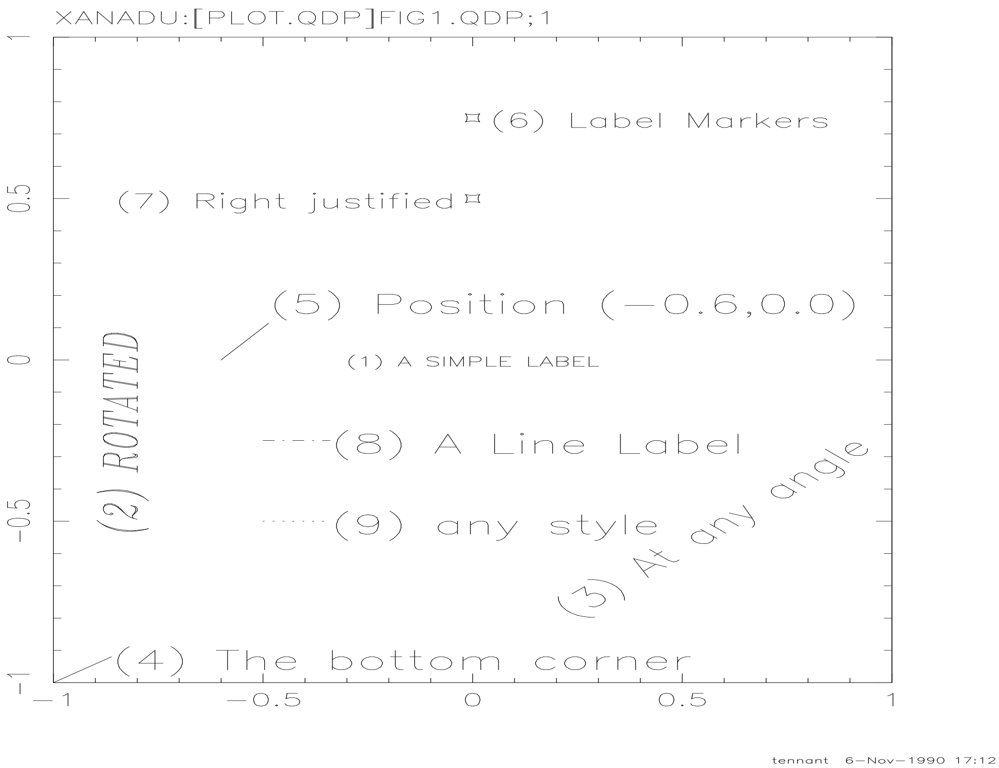
The `SPIRAL.QDP` file contains:

```
 1.0000  0.0000
-1.0000  0.0000
 0.9988  0.0491
-0.9988 -0.0491
 0.9952  0.0980
-0.9952 -0.0980
 0.9892  0.1467
-0.9892 -0.1467
 0.9808  0.1951
-0.9808 -0.1951
 0.9700  0.2430
-0.9700 -0.2430
 0.9569  0.2903
-0.9569 -0.2903
 0.9415  0.3369
-0.9415 -0.3369
 0.9239  0.3827
-0.9239 -0.3827
 0.9040  0.4276
-0.9040 -0.4276
    "       "
```




The `FIG1.QDP` file contains:

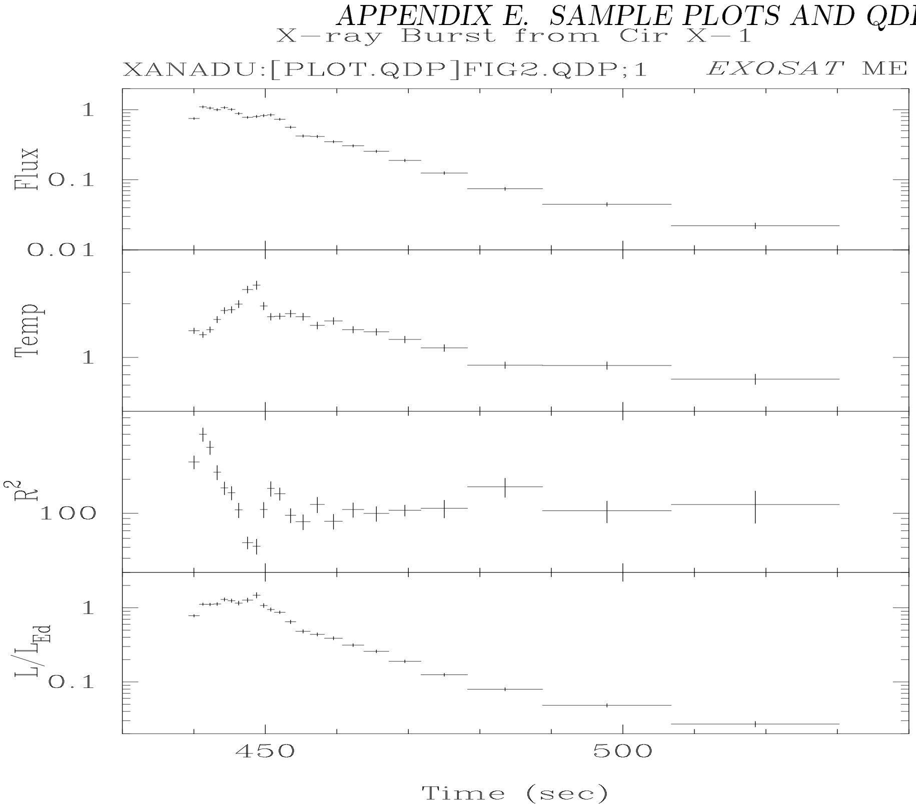
```
CS  1.3
GAP 0.0
LAB 1 "(1) A SIMPLE LABEL"
LAB 2 P -0.80 -0.50 J L RO 90 CS 2 "\FI(2) ROTATED"
LAB 3 P .6 -.5  CS 2 CO 3 RO 45 "(3) At any angle"
LAB 4 P -1  -1 LI 30 CS 2 CO 4 "(4) The bottom corner"
LAB 5 P -.6 0 LI 45 CS 2 CO 5 "(5) Position (-0.6,0.0)"
LAB 6 P 0. .75 MA 10 CS 1.5 CO 6 "(6) Label Markers"
LAB 7 P 0. .50 MA 10 CS 1.5 CO 6 J R "(7) Right justified"
LAB 8 P -.50 -.25 LI 0 LS 3 CO 8 CS 2 "(8) A Line Label"
LAB 9 P -.50 -.5  LI 0 LS 4 CO 8 CS 2 "(9) any style"
!
-1      -1
 1      -1
 1       1
```



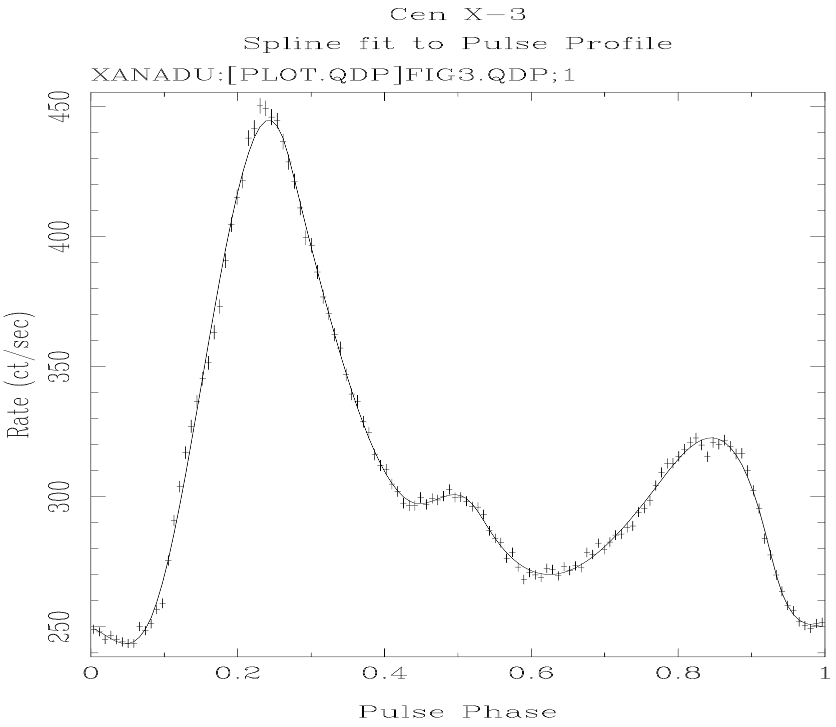

The `FIG2.QDP` file contains:

```
READ SERR 1 2 3 4 5
@"XANADU,PLOT/QDP,FIG2"      ! See PLT Command File "FIG2.PCO"
!
440.02 0.75  0.749 2.8E-2  1.41 5.2E-02  284.3 38.0  0.1445/.185 6.0E-03/.185  62.7
      "           "            "              "                 "                "
```

The above QDP file calls the PLT command file `FIG2.PCO`:




```
COL  OFF 1,6
CSIZ 1.3
FONT RO
LAB  1 CS 1.3 CEN BOT JUS RIG VP .9 .91 "\FIEXOSAT \FRME"
LAB  RO
LAB  T  X-ray Burst from Cir X-1
LAB  G1 Time (sec)
R    Y1 430 540
LAB  G2 Flux
R    Y2 .01 2
LAB  G3 Temp
R    Y3 .5 4
LAB  G4 R\U2
R    Y4 30 800
LAB  G5 L/L\DEd
R    Y5 .02 3
LAB  G6 Chi
LAB  POS Y 2.5
LOG  Y
P    V
TIM  OFF
VIEW .15,,.90
```

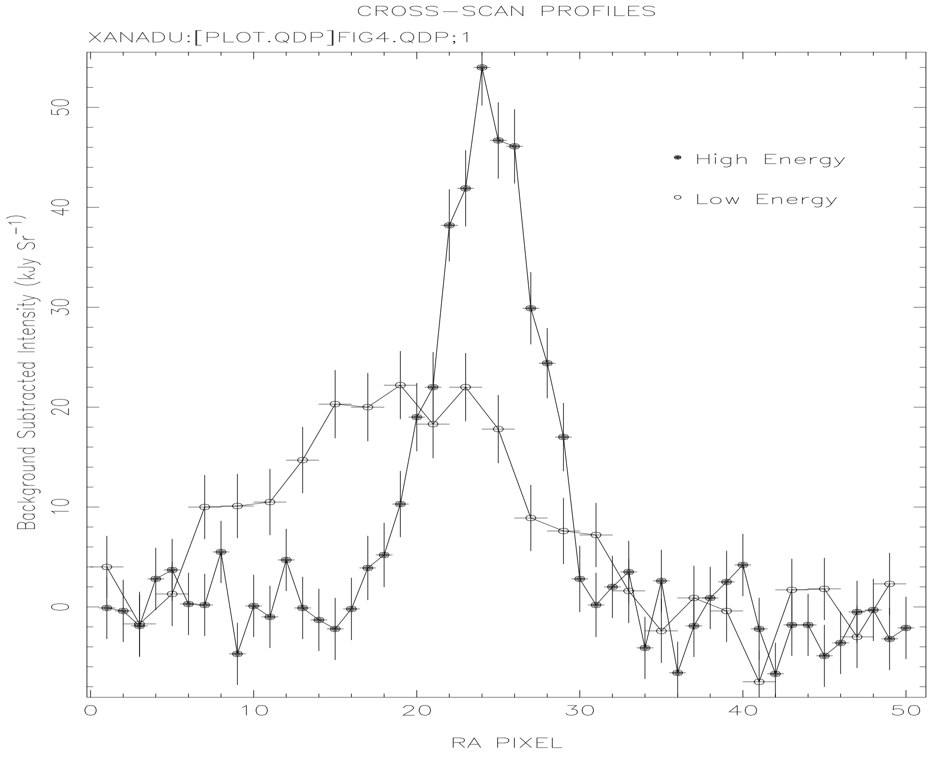



The FIG3.QDP file contains:

```
! FOLD.  Scatter errors.
! Start time(   82135.4), End time(   94966.3)
! Period( 4.827641200D+00), Phase 0( 4.000D-01), DPDOT( 0.000D+00)
READ SERR 1
XAXIS LIN  3.9062500E-03  7.8125000E-03
@"XANADU,PLOT/QDP,FIG3"      ! See PLT Command File "FIG3.PCO"
!
   249.0985       1.712956
   248.0650       1.642315
   245.0948       1.686881
   246.7742       1.685483
   245.0568       1.691913
      "              "
```

The above QDP file calls the PLT command file FIG3.PCO:

```
CSIZ 1.2
FONT RO
LAB  OT  Cen X-3
LAB  T   Spline fit to Pulse Profile
LAB  X   Pulse Phase
LAB  Y   Rate (ct/sec)
LAB  PAR OFF
MOD  @"XANADU,PLOT/QDP,FIG3"
R    X   0 1
TIM  OFF
VIEW .15 .15
```

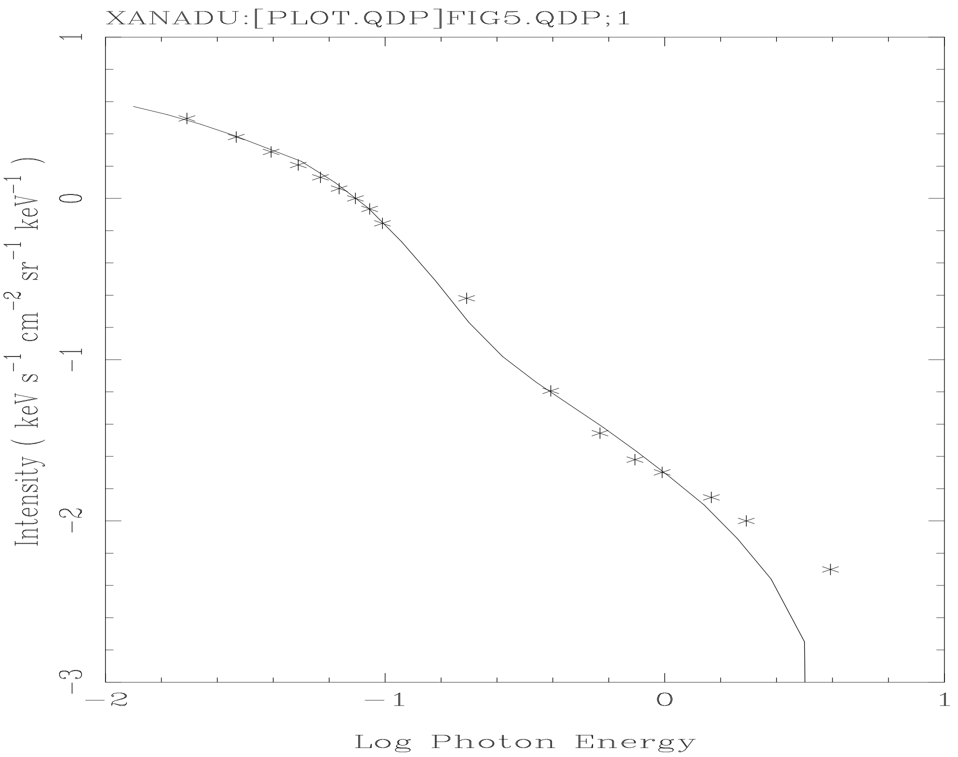



The FIG4.QDP file contains:

```
READ SERR 1 2
@"XANADU,PLOT/QDP,FIG4"       ! See PLT Command File "FIG4.PCO"
!
 1.00  0.50 -1.E-01  3.1
 2.00  0.50 -0.4  3.1
 3.00  0.50 -1.9  3.1
 4.00  0.50  2.8  3.1
 5.00  0.50  3.7  3.1
 6.00  0.50  0.3  3.1
 7.00  0.50  0.2  3.1
 8.00  0.50  5.5  3.1
 9.00  0.50 -4.7  3.1
    "          "
```

The above QDP file calls the PLT command file FIG4.PCO:

```
SKIP SING
LINE ON   1
MARK   17 ON   1
LINE ON   2
MARK   21 ON   2
MARK SIZE  1.5
LAB  1 MAR 17 JUS Lef
LAB  1 POS 36 45 "High Energy"
LAB  2 MAR 21 JUS Lef
LAB  2 POS 36 41 "Low Energy"
LAB  T  CROSS-SCAN PROFILES
LAB  X  RA PIXEL
LAB  Y  Background Subtracted Intensity (kJy Sr\u-1)
TIME OFF
```

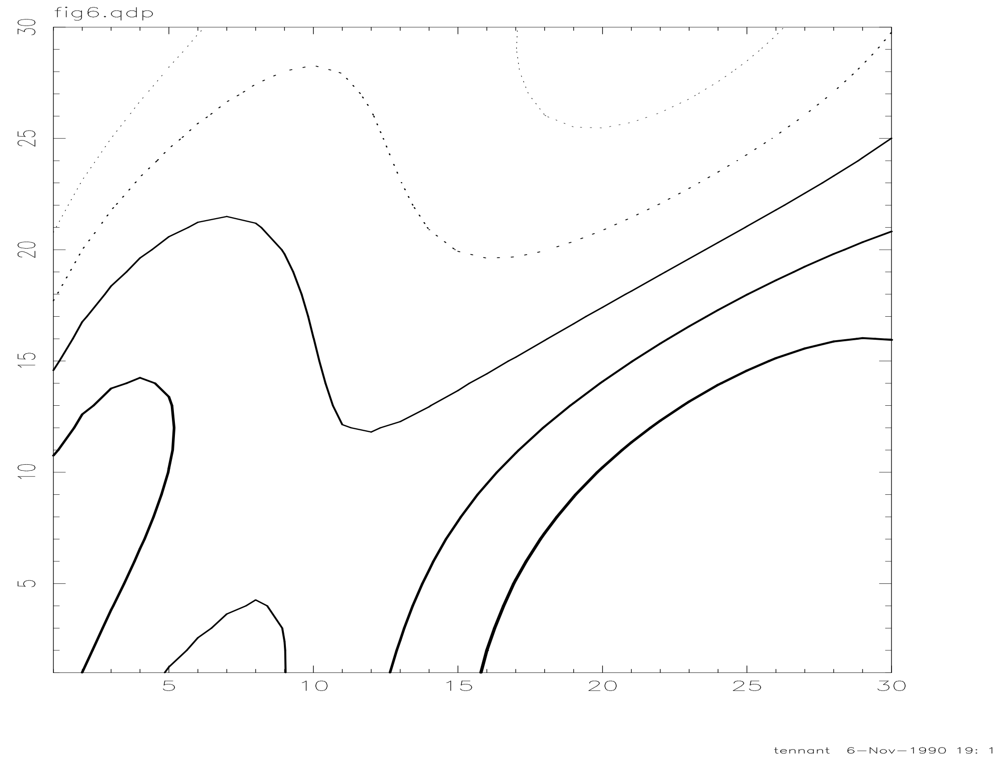



The `FIG5.QDP` file contains:

```
skip on
@"xanadu,plot/qdp,fig5"        ! See PLT Command File "FIG5.PCO"
  -7.300000     -0.6800003
  -7.180000     -0.4200001
  -7.060000     -0.1800003
  -6.940000      6.0000420E-02
  -6.820000      0.3000002
  -6.700000      0.5400000
  -6.580000      0.7700005
  -6.460000       1.010000
  -6.340000       1.240000
  -6.220000       1.450000
  -6.100000       1.750000
       "              "
```

The above QDP file calls the PLT command file `FIG5.PCO`:

```
CSIZ 1.3
FONT ROMAN
LAB  X Log Photon Energy
LAB  Y Intensity ( keV s\u-1\d cm\u-2\d sr\u-1\d keV\u-1\d )
LINE ON 1
MARK 3 ON 2
MARK SIZE 2.0
R   -2 1 -3 1
TIME OFF
```




The FIG6.QDP file contains:

```
COL OFF 1..999
CON LEV -1. -.5 0. .5 1.  LS 4 4 1 1 1   LW 1 2 3 4 5
XAX LIN   1 1
YAX LIN   1 1
R   1 30 1 30
!
 .748  .795  .826  .842  .841  .823  .788  .734  .664  .577  .474  .358  .228-
   8.700E-02 -6.300E-02 -.220 -.383 -.548 -.713 -.876 -1.035 -1.187 -1.331-
  -1.464 -1.585 -1.692 -1.783 -1.859 -1.917 -1.958
 .499  .574  .639  .691  .731  .755  .764  .756  .731  .689  .631  .555  .464-
   .358  .239  .107 -3.400E-02 -.184 -.340 -.500 -.662 -.823 -.981 -1.135-
  -1.281 -1.418 -1.545 -1.658 -1.758 -1.842
 .281  .364  .442  .513  .573  .622  .658  .681  .688  .679  .654  .613  .556-
   .483  .395  .292  .177  5.000E-02 -8.600E-02 -.230 -.381 -.535 -.691 -.846-
  -.999 -1.147 -1.289 -1.422 -1.544 -1.654
   "
```