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RESPECT—Software Package for Reduction of Astronomical Spectra

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Abstract. The interactive software package RESPECT developed for reducing astronomical spectroscopic data at Vainu Bappu Observatory (VBO), Kavalur, is described. Each command of RESPECT performs a simple operation on a one-dimensional image. Several commands can be stringed together to perform higher-order operations. The hardware and software environments of RESPECT include VAX VMS version 3.5 and its utilities and runtime libraries, Tektronix 4115B colour monitor with Tektronix 4691 colour copier and the basic command set of Tektronix Interactive Graphic Library (IGL). Additional optional environ- ments include Digital VT125 and VT240 series monitors with Digital ReGis Graphic Library (RGL) and Printronix printer/plotter with Digital PLXY software.

Key words : reduction techniques, software—spectroscopy, reduction software

Introduction

With the introduction of digital microdensitometers, and digital data acquisition systems for photoelectric, television-type, and solid-state detectors, several software packages are continuously being developed for reducing digital data. A continuous development of software and hardware environments in the computer world has provided added impetus to software development. In astronomical spectroscopy, particular mention may be made of the ELSPEC package at the astronomical observatory of Trieste (Rusconi & Sedmak 1979); the REDUCE package of the Dominion Astrophysical Observatory (Hill, Fisher & Poeckert 1982); the RETICENT package (Pritchet, Mochnacki & Yang 1982); and the SPICA package of STARLINK.

The availability of digitizing microdensitometers at the Indian Institute of Astrophysics (IIA) motivated us to develop software for the digital reductions of spectroscopic data. The first of the digital microdensitometers at IIA used the table-top microcomputer HCL Micro 2200 with a floppy disc drive for data

acquisition and storage, controlling a Carl-Zeiss microdensitometer (Viswanath 1980). Since it was not possible to transfer these data to any main frame computer, reduction programs were developed and used on the microcomputer itself (*cf.* Giridhar 1983; Prabhu 1983). Later, Ananth (1986) coupled the C–Z microdensitometer to the ECIL TDC-316 computer which made it possible to store the data on a magnetic tape. Since a VAX 11/780 system was now available at VBO, an interactive program was developed and used for the reduction of photographic spectra (*cf.* Prabhu & Anupama 1987a; Anupama & Prabhu 1987). However, it was soon found that large single programs are difficult to debug and extend, and also tend to get too rigid for manipulation by the user. Hence a new concept was introduced of using a large set of small individual FORTRAN routines.

This concept is similar to the ones used in advanced astronomical software packages that are freely available. However, it was found desirable to develop at least a small package locally. First, such a package could be quickly made available for reducing immediately the existing spectroscopic material. Secondly, it would create the environment for familiarizing oneself with digital reduction techniques. Finally, the experience gained in developing the software would prove useful in adapting and using more sophisticated packages.

These considerations motivated the development of RESPECT package, which is now in regular use at VBO (Balasubramaniam 1987; Prabhu & Anupama 1987b).

2. The concept

The RESPECT package consists of a large number of short executable images of routines originally written in FORTRAN 77, including the run-time library of VAX VMS 3.5. Each image is activated through an intelligible command defined using Digital command language definition utility. For example the command

\$ ADD *infile 1 infile 2 outfile*

co-adds data in *infile 1* to data in *infile 2* over the common range in x, and stores the result in *outfile*. The operating system allows grouping of a string of such commands as a command procedure and activating this procedure through another command defined using symbol definition. Thus, one may define a command

\$ BAKER *infile outfile*

to convert photographic densities into Baker-transformed densities ($B = \log(10^D - 1)$ through a command procedure :

```
$ 'R10 P1 TR10          ! raise data in infile to the power of 10
$ SUBC TR10 TSUBC 1     ! subtract 1 from the data in TR10
$ LOG TSUBC 'P2         ! obtain logarithm of data in TSUBC and store
                          the result in outfile
$ DELETE TR10.DAT;, TSUBC.DAT; : Delete temporary files
$ EXIT
```

Some such command procedures are already available. The users are encouraged to write their own command procedure so that they have a control over what is being done to their data.

The basic commands of RESPECT generally have qualifiers to initiate different kinds of action. For example, the command AVER/BLIND obtains a blind average of the data, whereas the command AVER/INT enables choice of the regions of data to be averaged, interactively through the Tektronix terminal. Any number of qualifiers can follow one another as long as they are compatible with each other. Some qualifiers have the format

/qualifier = "value".

If any of the parameters, or values of qualifiers contain characters other than Roman capital letters and numbers, they should necessarily be inserted between double quotes. Otherwise the double quotes may be dropped.

The commands and qualifiers are recognized by only the first four characters. It is thus possible to abbreviate the longer commands and qualifiers.

The command language can manipulate integer data and character-string data used either explicitly or stored as symbols. Such symbols can be transferred back and forth between Fortran routines and the command environment. Hence some of the RESPECT commands have the provision and/or need to define a symbol and assign a desired value to it.

3. The environment

The RESPECT package is developed with VAX VMS version 3.5, the Digital command language definition utility, and the Digital run-time library. In addition, the display on the terminal is achieved through the basic command set of the Tektronix interactive graphic library (IGL). Some display routines are also available that employ the Digital ReGis graphic library (RGL). The plotting routine on the Printronix printer/plotter utilizes the Digital PLXY software. The final figures for publication can be composed on the Tektronix 4115B terminal and a hard copy obtained on the Tektronix 4691 colour copier. The interactive graphic commands employ the IGL routines.

The input and output data of RESPECT commands (excluding the reformatting commands) are stored in the internal format of the system which reduces the input/output time, and retains the full accuracy of the system. The data may be of three types :

R : real data at uniform intervals where only the initial value of X and its increment are stored instead of the complete X array.

C : complex data at uniform intervals where the real and imaginary parts are stored as adjacent pairs of data.

P : paired data stored as (X, Y) pairs.

The data are arranged into the following records.

Record 1 : The name of the file containing the original data which entered the RESPECT package (16 characters); header of this file (80 characters);

name of the current file (16 characters); and the header generated by the program (80 characters) describing the operation performed by the current program.

Record 2 : The number of data points; x and y coordinates of the first data point; increment along the x-axis between successive points of sequential data (data type R and C; a dummy value is stored for paired data); the data type (R, C, or P); the value of the first data point; and 30 parameters which may store the intermediate variables needed to be passed from one program to another, or the results that do not fit in into the general format of record 3.

Record 3 : The data points beginning with the second one stored consecutively for type R, as pairs of (real, imaginary) parts for type C, and as (x, y) pairs for type P. The maximum length of this record is 8191 variables.

Occasionally it has been found useful to accommodate more data sets repeating records in the formats of records 2 and 3, but this has not yet been made a general rule.

4. The commands

The RESPECT commands can be subdivided into the following groups : (i) Entry and exit; (ii) The basic command set (BASCOM); (iii) Spectroscopic extensions (SPEX).

4.1. *Entry and exit*

The entry into the RESPECT environment is activated by the command

```
$ RESPECT
```

When one enters the RESPECT environment, several new symbols are placed in the user's symbol table. If a user had defined some symbols previously, some of them may get redefined. Similarly, the diminutives of some of the system commands may become ambiguous, and one may need to give the full command when needed. An example is the LOGOUT command. Though normally it is enough to say LO to log out, when RESPECT is active, the RESPECT command LOG makes the command ambiguous upto the level of LOG. If one spells upto LOGO or beyond, the command LOGOUT can be executed.

While one is in the RESPECT environments, the command

```
$ HELP
```

helps with the use of individual commands of RESPECT.

One may exit from RESPECT by entering the command

```
$ QUIT.
```

This command looks for the user's LOGIN.COM file and executes it, and hence, if the user has defined some symbols through his LOGIN.COM, they become once again active. If he has no such symbols defined, there is no effect of QUIT command. The RESPECT commands that are not redefined by this process remain active until the user logs out.

4.2. *The Basic command set (BASCOM)*

The basic command set of RESPECT can be subdivided into following classes : (i) Reformatting commands (IO); (ii) Graphic action commands (GRAPH); (iii) Pixel-finding routines (PIXEL); (iv) Averaging and convolving routines (CONVOL); (v) File manipulation commands (FILE); (vi) Arithmetic operation commands (MATH); (vii) Curve-fitting and curve-generating commands (CURVE); (viii) Fast Fourier transform (FFT); (ix) Coordinate—scaling commands (SCALE); (x) Calculator command (CALC); (xi) Practical Astronomy command (PRACT).

Each command requires some parameters which generally include the names of input file and output file. Each command may have an optional or necessarily required qualifier to affect different actions. A complete list of commands and their qualifiers is given in table 1. A brief description is given in the following subsections.

Table 1. The basic command set of RESPECT (BASCOM)

Class	Command	Qualifiers	Parameters
IO	REFORM	/PDS	infile outfile
		/TDC	
		/TAB	infile
	OUTPUT	/TYPE	infile 1, infile 2,.....
		/PRINT	
GRAPH	DISPLAY	/TEK	infile 1, infile 2,.....
		/VT	
		/RGL	
		/LINE=*n*	
		/CLR=*n*	
		/DX=*c*	
		/LEGEND	
		/XAXIS="label"	
		/YAXIS="label"	
		/VEL="rest wavelength"	
	PLOT	/LINE=*n*	infile 1, infile 2,.....
		/SYM=*n*	
		/XAXIS="label"	
		/YAXIS="label"	
		/FACT=*f*	
		/LENGTH=*l*	
PIXEL	EXAMINE	/FS	file
		/VT	
	WEEDOUT	/LEGEND	infile 1, infile 2...outfile
		/XAXIS="label"	
		/YAXIS="label"	
		/VT	
	WLID	/FS	infile linelist outfile
		/VT	
	CTMFIT	/FS	infile outfile
		/VT	

(*Continued*)

Table 1. (*Continued*)

Class	Command	Qualifiers	Parameters
CONVOL	AVER	/BLIND /RES="Symbol" /INT /VT	infile outfile
	RAVE		infile outfile 1st-pt half-width function
	INSTRES		infile std-flux outfile
FILE	JOIN	/TYPE="type"	file 1 file 2 outfile
	PAIR	/X /Y /XY=("x-name", "y-name")	file X file Y outfile
	REAL		infile outfile
	IMAG		infile outfile
	EXTRACT	/PART="part" /PART=(*n*, *m*)	infile outfile
	REFLECT	/REFPT="reference point"	infile outfile
	REVERSE		infile outfile
	CENTRE		infile outfile
	CLIP	/LIM=("lim 1", lim 2") /PT /INT /FS /VT	infile outfile
	LINES	/FS /VT	infile outfile linelist
FILE	EXTEND	/L=(*n*, "value") /R=(*n*, "value") /FITIN=("Sym 1" "Sym 2") /ENDMASK=percent	infile outfile
MATH	ADDC		infile outfile "constant"
	SUBC		infile outfile "constant"
	MLTC		infile outfile "constant"
	DIVC		infile outfile "constant"
	ADD	/WINDOW='W' /AVER	file 1 file 2 outfile
	SUBT	/WINDOW='W'	file 1 file 2 outfile
	MULT		file 1 file 2 outfile
	DIV		file 1 file 2 outfile
	LOG		infile outfile
	R10		infile outfile
	MOD2		infile outfile
CURVE	POLFILT	/P=*n* /EPS=*e* /LEGEND="legend" /XAXIS="label" /YAXIS="label" /VT	infile outfile

(*Continued*)

Table 1. (*Continued*)

Class	Command	Qualifiers	Parameters
CURVE	GAUSS	/VT	infile outfile
		/PAR=(n, $x1$, dx)	infile outfile
		/PFILE="file"	
	PSHIFT	/DX=dx	infile outfile
		/REV	
	SPLINE	/PAR=(n, $x1$, dx)	infile outfile
		/PFILE="file"	
	FILTER	/LC="cut-on"	outfile n dx
		/HC="cut-off"	
FFT	FT	/INV	infile outfile
		/DX="symbol"	
SCALE	WSCALE		infile outfile scalefile
	YPRIM		infile outfile scalefile
	MAGN		infile outfile mag
CALC	CALC		operand operator "function" result
		/FUN	argument "function" result
		/DEG	
PRACT	ATMEX		infile outfile

4.2.1. *Reformatting commands* (*IO*)

The IO commands convert data in ASCII format to the internal format of RESPECT, or vice versa. The microdensitometric data are assumed to have been converted to ASCII using programs pre-existing at VBO. The default qualifier for REFORM is /PDS. The qualifier /TAB allows converting tabular data into the RESPECT format.

The OUTPUT command types the data on the screen of the monitor (/TYPE) or prints it on the printer/plotter (/PRINT).[1] The default qualifier is /TYPE.

4.2.2. *Graphic action commands* (*GRAPH*)

The GRAPH commands are specially suited for displaying or plotting the contents of a file. The DISPLAY command displays the data on either the Tektronix monitor (qualifier /TEK which is default), or on VT 240 terminal (qualifier /VT). The qualifier /RGL enables display using RGL routines. PLOT command plots the data on Printronix printer/plotter. In both these commands qualifiers /XAXIS = "label" and /YAXIS = "label" enable a choice of labels for x-axis and y-axis, respectively. A list of filenames separated by commas are accepted by these commands. The plots of data in all these files are superposed.

The qualifier /LINE = n with n a desired integer is valid for DISPLAY and PLOT commands. In the former case, n = 1–10 generate different kinds of dashed or dot-dashed lines to join the 'R' type data points plotted. If n = "C" the data points are joined by a continuous line. The default value of the qualifier is /LINE

[1]The routine enabling this command uses the Fortran statement WRITE (8, *format*). This statement cannot be executed from some of the user accounts at VBO. In such a case the SPEX command PRTFILE will be useful.

= "C". $n > 10$ results in discrete-point plots. For 'P' type data, n is always assumed to be 11. If more than one file is to be displayed, the input value of n is ascribed to the first file and automatically incremented for successive files.

In the case of PLOT command, for $n < 0$ the points are not joined, for $n \geqslant 0$ they are joined, and every nth point is marked by a special symbol. The default value is $n = 0$. The qualifier /FACT = f ($f \leqslant 3$) helps magnification or reduction of the entire plot. /LENGTH = l enables choice of the length of x-axis.

If one has paired data, DISPLAY command automatically chooses one symbol for each file. On the other hand, PLOT command allows a choice of symbols with the help of the qualifier /SYM = n, where n = 1–31.

The DISPLAY command allows plotting the 'R' type data with x-axis decreasing to the right when the increment dx is negative. The corresponding qualifier is /DX = "S". The qualifier /VEL = "λ_0" converts the x-axis to velocity scale from wavelength scale.

The DISPLAY has two other qualifiers available. /CLR = n with n = 1–16 allows a choice of colours for the display of data. When this qualifier is present, the colour is automatically changed from one file to another. /LEGEND enables a choice of legends for each line/colour at the foot of the figure. This qualifier is useful in the preparation of final figures for publication. An example of DISPLAY is shown in figure 1.

The qualifiers /CLR, /LINE, /LEGEND, /VEL, and the facility of superposition are not available with DISPLAY /RGL command.

4.2.3. *Pixel-finding commands (PIXEL)*

The pixel-finding commands enable measurement of the coordinates of a desired point in a plot (EXAMINE). As special cases, the WLID and CTMFIT commands enable measurement of spectral lines of interest, and identification of the continuum points, respectively. With all these commands, the display normally occupies the middle half of the screen (leaving out the top and bottom quarters). If a full-screen display is desired, one only needs to use the /FS qualifier.

The WEEDOUT command enables interactive deletion of (x, y) pairs from a 'P'-type data file. The qualifiers have similar meaning as in the case of DISPLAY command. If one gives more than one input file, it is assumed that one wishes to delete points from the last file, and the remaining files are only to be displayed. This helps, for example, in examining continuum points superposed over a star spectrum, and in deleting the points that do not fit satisfactorily.

The qualifier /VT enables use of these commands on the VT 240 series terminals, instead of the Tektronix terminal.

4.2.4. *Averaging and convolving routines (CONVOL)*

Average value of the 'R' type data in the entire file may be obtained using the AVER command (default qualifier /BLIND). The qualifier /RES helps storing the result as a symbol. The qualifier /INT enables a choice of the region or regions to be averaged, interactively, on a Tektronix terminal or on a VT terminal using the

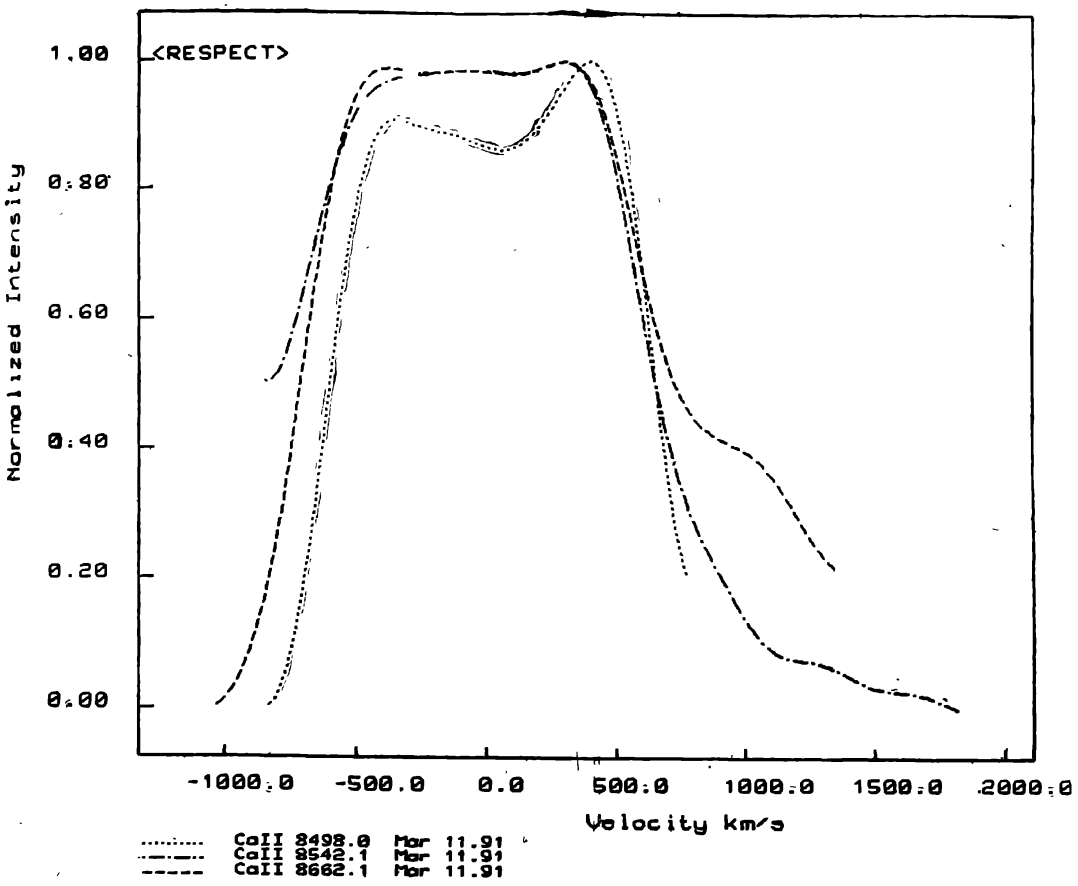

Figure 1. An example of the command
$ DISPLAY/TEK/XAXIS="Velocity km/s"/YAXIS="Normalized Intensity"/LEGEND/LINE file 1, file 2, file 3.

qualifier /VT. The average values and positions of individual regions are stored as (x, y) pairs in the output file, if specified.

The RAVE command smooths the data by the method of running averages with a weighting function of desired width. The available weighting functions are step-function (C), triangular function (T), and Gaussian function (G). Since these functions are symmetric, the procedure is equivalent to a convolution.

The INSTRES command is specially designed to determine the instrumental response using the instrumental logarithmic intensities of a standard star, and its standard flux values. The command first obtains the logarithmic intensity at standard wavelengths, averaged over the bandpass, and then subtracts them from standard (logarithmic) fluxes to obtain the instrumental response. These corrections can be applied to the spectrum of the program object by spline interpolation. Figure 2 shows an example of instrumental response plotted using PLOT command.

4.2.5. *File manipulation commands (FILE)*

File manipulation commands include commands to generate paired data (JOIN, PAIR); to extract a part of the data (REAL, IMAG, EXTRACT, CLIP, LINES); to extend the data (EXTEND); or to reflect, reverse, or centre linear data.

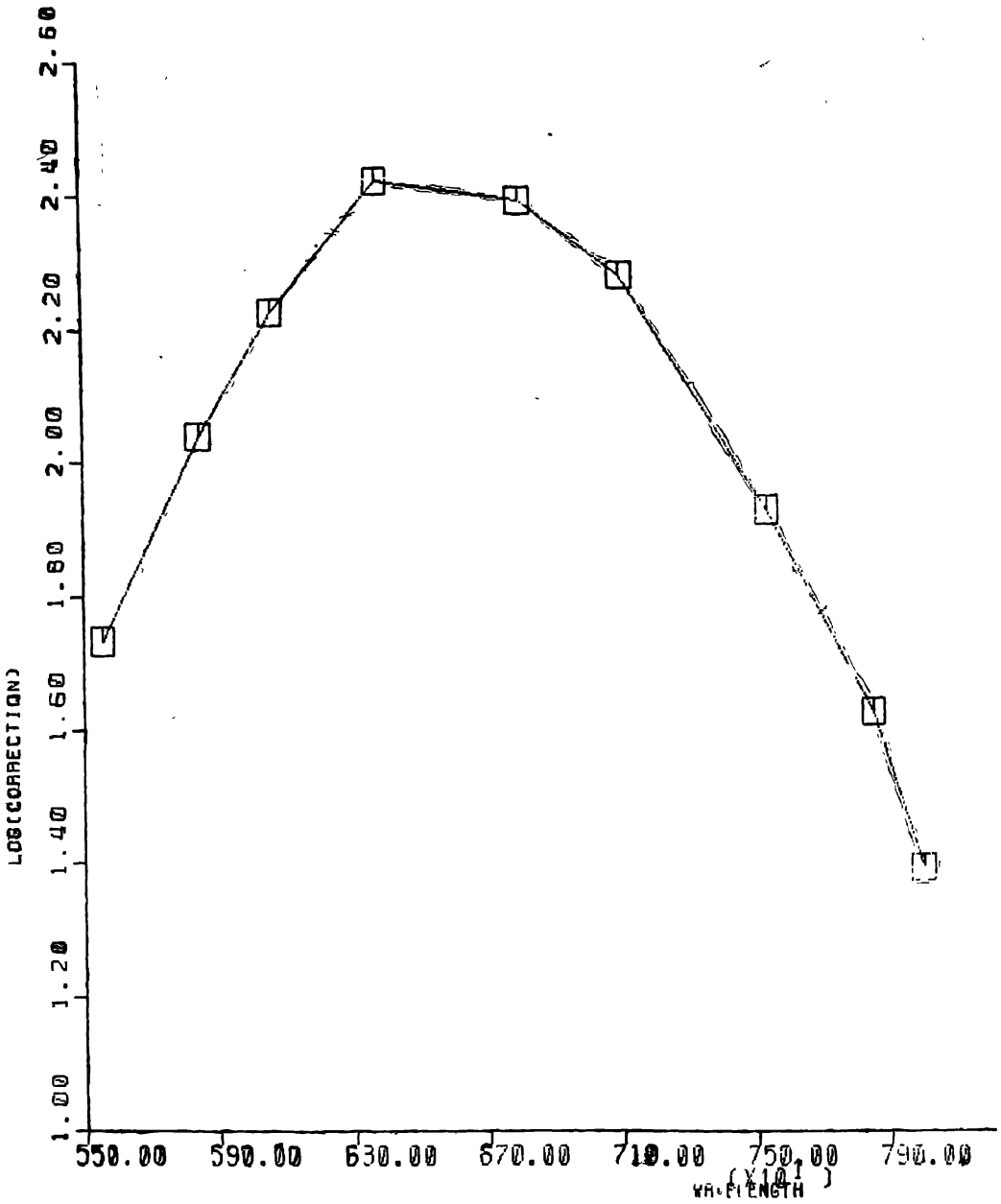

Figure 2. An example of the PLOT command. The instrumental response points which are plotted were obtained using the INSTRES command.

The JOIN command merges two 'R' type files, one containing the x values, and the other containing the y values (TYPE = p). to form a 'P' type data set. It can also be used to merge two sets of 'R' type data as real and imaginary parts of a complex data file. The PAIR command can also be used similarly to generate (x, y) pairs. This command enables interactive rejection of points from x or y files (/X, /Y). The qualifier /XY = ("x-name", "y-name") enables prompting of the identification of x and y data during the interactive session.

REAL and IMAG commands extract the real and imaginary parts of a complex data file. Similarly, the EXTRACT/PART = "part" command extracts the X or Y part of a paired data set (/PART = X or /PART = Y). The qualifier /PART = (n, m), extracts every mth point from an 'R' type data set, beginning with the nth point.

The REFLECT command replaces the second half of a linear image with the reflection of the first half about the centre. Reflection of the image about a desired point is achieved using qualifier /REFPT = "reference point". REVERSE command reflects the entire image about the centre. The CENTRE command assumes that the data repeat over a period equal to the length of the data, and translates it by half this period. Thus, the zero of the x-axis shifts from the first point to $(\frac{1}{2}n + 1)$th point.

The CLIP command trims the edges of a linear image at the limits given by the qualifier /LIM = ("lim 1", "lim 2") if present. If the limits supplied are not x-coordinates, but the serial numbers of data points, the qualifier /PT should be specified. The clipping can on the other hand be done interactively using the INT qualifier. In this case /FS and /VT have functions similar to the case with other interactive graphic commands.

The LINES command also clips a file interactively, and offers the possibility of extracting different segments of an image, and storing them as separate records. This is useful for separating different spectral lines in a spectrum for further processing, such as fitting a Gaussian [see GAUSS in class CURVE (section 4.2.7)]. The LINES command also computes the area under the curve in each segment, estimates its halfwidth, computes the position and value of maximum/minimum and position of the centroid, and identifies whether the line is an emission or absorption type.

The EXTEND command appends a desired number of points to the left (/L = (n, value)) and/or to the right (/R = (n, value)) having a constant value. If the character L is supplied instead of a number for the value, the first and last value of the original data set are used for the constant. If the qualifier /FITIN is present, the number of points to be added to the left and right are computed internally so that the total number of points is 2^k with k an integer, and the original image is centred with respect to the final data length. In such an event, the parameter n in /L and /R qualifiers is a dummy. The /FITIN command is useful in preparing an image for Fourier analysis using the FFT routine. If one specifies the symbol names 'npt' and 'mpt' using the qualifier /FITIN = (npt, mpt), the values of initial and final data lengths are stored in these symbols. The qualifier /ENDMASK is also useful while obtaining a Fourier transform. It applies a cosine-bell mask over ten per cent of the data at either ends. If a different percentage is desired, it may be specified. When the qualifier /FITIN is present, the /ENDMASK brings the final level to the mean of the first and the last data points.

4.2.6. *Arithmetic operation commands* (*MATH*)

The arithmetic operation commands execute arithmetic operations on individual data points of a linear image. ADDC, SUBC, MLTC, DIVC, add, subtract,

multiply by, or divide by a constant all the data points in the input file. Note that if the constant includes a decimal point and/or a negative sign, the entire value should be enclosed in double quotes. The commands ADD, SUBT, MULT, DIV do the specified operations over the corresponding points of the images in the two input files over the common range of x. The interval Δx is assumed to be the same for both the files, but a warning is flashed if they are not. The command LOG converts all the data points to their logarithm to the base of 10, and R10 does the inverse operation of raising them to the power of 10. In the case of overflow or underflow, the LOG command just stores zero as the value of the corresponding point whereas R10 stores the value 1. MOD2 obtains the modulus-squared of the data points in a complex image.

The commands ADD and SUBT can be executed over a specified window (C : common range; U : total range; F, S : range of first or second data file; or W1, W2). ADD/AVER averages the data over the specified window.

4.2.7. *Curve-fitting and curve-generating commands (CURVE)*

The curve-fitting command POLFIT fits a polynomial of order $n \leqslant 5$ (/P = n) interactively. The qualifier /EPS = e enables automatic rejection of points that deviate by more than $e\sigma$. The qualifiers /LEGEND = "legend", /XAXIS = "label", /YAXIS = "label" help in adding a legend at the foot of the figure showing the fit, and in labelling the axes. GAUSS obtains a Gaussian fit and displays on the monitor. Figure 3 shows an example of a photographic characteristic curve fitted using the POLFIT command Figure 4 shows the Gaussian fit to an emission line. The qualifier /VT has the same function, as in other interactive graphic commands, in both POLFIT and GAUSS.

The curve-generating command PLNM generates a polynomial based on the coefficients stored in the input file whereas the command SPLINE generates a natural-cubic-spline-interpolated curve using the points stored in the input file. Both these commands generate the curve over the range specified through the number of points to be generated, the initial x-coordinate, and the interval dx between successive points. These values are either passed explicitly through the qualifier /PAR = (n, x1, dx) or taken from an image file specified through /PFILE = "file".

The command PSHIFT transforms the polynomial coefficients in the input file under a translation by an amount dx specified through the qualifier /DX = dx. If the qualifier /REV is present, it is assumed that the curve is to be reflected about $x = 0$ and then translated by an amount dx.

The command FILTER generates a filter with cosine-bell edges, and is particularly suitable for generating filters for action in Fourier space. The filter is constructed over the range $x = 0$ to $(n - 1)$ dx, with n assumed to be 2^k. The filter is symmetric about $(\frac{1}{2}n + 1))$th point. The cut-on and cut-off limits are specified through the qualifiers /LC = cut-on, and /HC = cut-off.

POLFIT uses the Cracovian matrix method of least-square solution (Kopal 1959) and is adapted from a Fortran program developed by A.V. Raveendran (1980, personal communication). GAUSS uses an algorithm due to von Hoerner (1967),

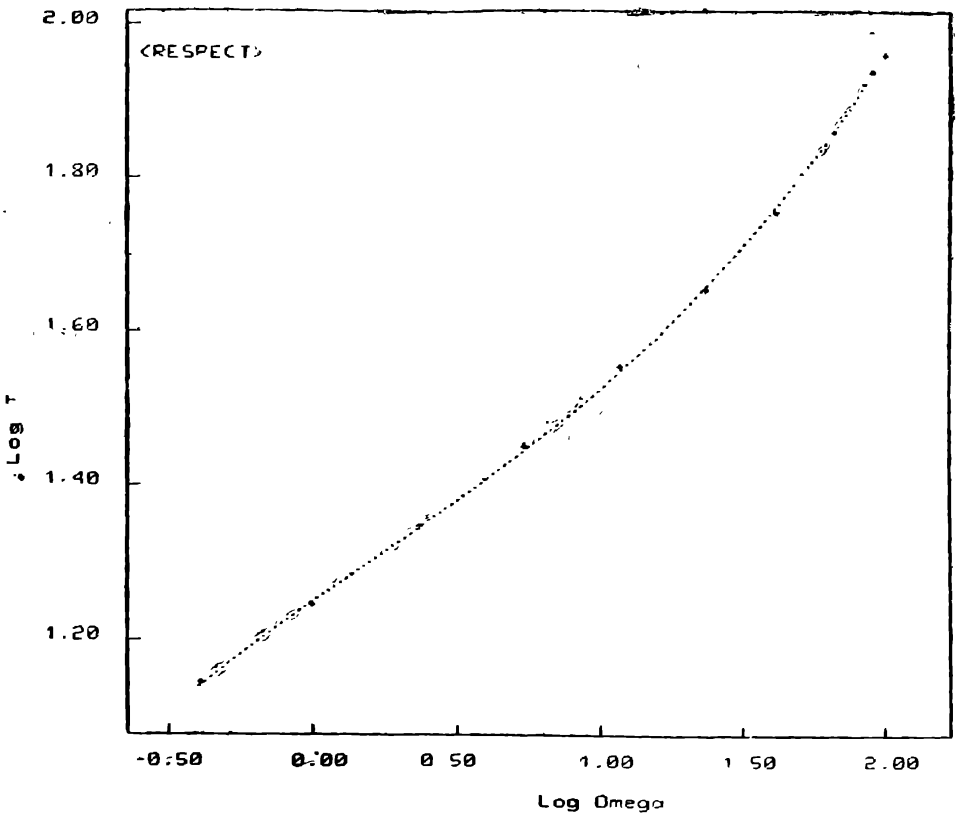

Figure 3 Polynomial fit to the photographic characteristic curve obtained using the POLFIT command.

and is adapted from a Fortran routine developed by R. Duemmler (1986, personal communication). SPLINE uses routines due to Pennington (1965).

4.2.8. *Fast Fourier transform (FFT)*

The command FT obtains a direct Fourier transform of data in the inpute file. An inverse transform is obtained if the qualifier /INV is present. At times the information on the interval dx between successive points in the Fourier space may be required as a symbol. In such a case the qualifier /DX = "Symbol" places it against the desired symbol. The FT command uses an IBM fast Fourier transform routine adapted from Gray (1976).

4.2.9. *Coordinate-scaling commands (SCALE)*

The commands WSCALE and YPRIM transform x and y axes, respectively, under a power-law transformation. The command WSCALE is so termed since it is expected to be used most often in transforming the spectrum from position or pixel number to the wavelength scale

$$\lambda = a + bx + cx^2 + \ldots .$$

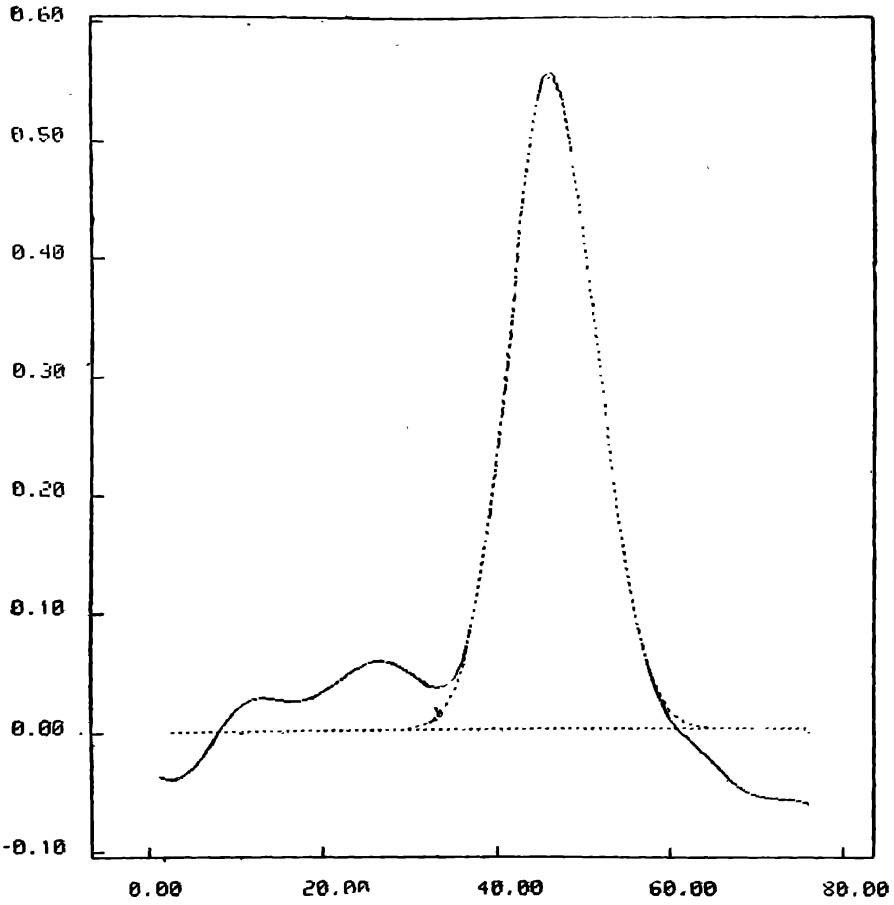

Figure 4. Gaussian fit to the Hα emission profile in T CrB obtained with the GAUSS command. Solid curve: observed profile; dashed lines : Gaussian curve and baseline fitted by the program.

This command spline-interpolates the observed spectrum at uniform intervals on the new (say, wavelength scale), and thus performs the operation commonly called as linearizing or scrunching.

The command YPRIM converts the entire data (y) to $y' = a + by + cy^2 + \ldots$. It is useful in converting the data from Baker-transformed densities (log ω) to logarithmic relative intensities (log I) when a power-law characteristic curve is available as log $I = f$ (log ω).

The MAGN command is not exactly a scaling command since it keeps the image unscaled. However, it spline-interpolates at finer intervals ($dx' = dx/\text{mag}$, where mag is a magnification factor). If a real magnification is required, one can use the WSCALE command with $x' = mx$ (i.e., $b = m$, $a = c = \ldots = 0$).

4.2.10. *The calculator command (CALC)*

The calculator command CALC performs simple arithmetic operations (+, —, /, *) on the values stored as symbols corresponding to the operand and the operator, and stores the result as a desired symbol. The qualifier /FUN enables obtaining the value of desired function (trignometric, exponential, etc.). In the case of trignometric functions, the argument is assumed to be in radians except when /DEG is present, when it is understood to be in degrees.

4.2.11. *Practical astronomy command (PRACT)*

The PRACT command ATMEX computes the atmospheric extinction correction for the spectrum in *infile*, and stores the correction in *outfile*. As intermediate calculations, it also precesses the coordinates, computes Julian day (JD), local sidereal time (LST), hour angle (HA) and airmass (AIRMASS). Before executing this command one needs to input the following parameters as symbols :

$ DATE : = dd : mm : yy
$ UT : = hh : mm : ss
$ RA : = hh : mm : ss
$ DEC : = dd : mm : ss
$ EPOCH: = year·decimal-fraction.

The output values of JD, LST, HA, AIRMASS, and precessed values of RA, DEC are stored as the respective symbols.

The Fortran routines required by ATMEX have been adapted from Henden & Kaitchuk (1982).

4.3. *The spectroscopic extensions (SPEX)*

The BASCOM commands provide the basic command set needed by most of the requirements of processing of a one-dimensional image. These commands can be stringed together to generate a higher-order operation. Some operations required in photographic spectrophotometry are of basic though of special nature, and these are also provided in RESPECT software. These SPEX commands activate command procedures and hence they do not contain any qualifiers. Also there is no provision of listing parameters using a comma as a separator. A complete list of SPEX commands is given in table 2. A brief description follows. Some SPEX commands are interactive in nature and can also be executed on VT 240 series terminals by specifying the parameter VT.

Table 2. The SPEX commands

Command	Parameters
PRTFILE	file 1 [file 2 file 3...]
DENSIT	infile outfile [clear dark type]
CALIB	infile outfile clear [VT]
PLOG	infile outfile
PSEG	infile outfile nseg
OPTIM	infile outfile
SMOOTH	infile outfile [VT]
LINT	infile outfile calfile
BKGD	infile outfile background calfile [VT]
CTMR	infile outfile ctmfile [VT]
FREG	infile outfile ctmfile

The SPEX command PRTFILE is not specific to spectroscopic reductions, but is equivalent of the BASCOM command OUTPUT/PRINT (*cf.* footnote 1).

The command DENSIT converts the transmission data to ordinary (type = D) or Baker-transformed (type = B) densities. If the values of clear, dark and type

are not provided the input is assumed to be of type D and is converted to Baker transformed densities.

CALIB helps in identifying the calibration steps or spots interactively, and fitting a polynomial to the logarithmic intensities as a function of Baker-transformed densities. It assumes the input-file to be in ordinary densities, and stores the coefficients of the polynomial fit in the output file.

PLOG and PSEG obtain power spectra using FFT routine. PLOG obtains logarithmic raw power spectrum whereas PSEG obtains a segmentally averaged power spectrum, by splitting the data into 'nseg' segments, and translating it by half the segment-length between successive power spectra. The resolution is correspondingly reduced, but the power spectrum is much smoother.

OPTIM constructs on optimal filter to be employed in smoothing the data (Brault & White 1971). The range over which the signal and the noise, respectively dominate are chosen interactively by examining a segmentally averaged power spectrum of the raw data. However, the signal is assumed to be Gaussian and hence the filter is useful only when the data contains a large number of Doppler-broadened lines.

The SMOOTH command helps in interactive smoothing of data using Fourier techniques. The data are initially divided into desired number of segments and an averaged power spectrum is obtained. One then decides whether an optimal filter or low-pass filter is to be applied. The power spectrum is examined and the various frequency limits are supplied in order to construct the filter. The filter is then constructed, and applied to the data to obtain a smoothed spectrum.

An example of raw spectrum and one smoothed using a low-pass filter are shown in figure 5. A batch-processing version of the SMOOTH command can easily be constructed by the users themselves if the frequency limits are already decided.

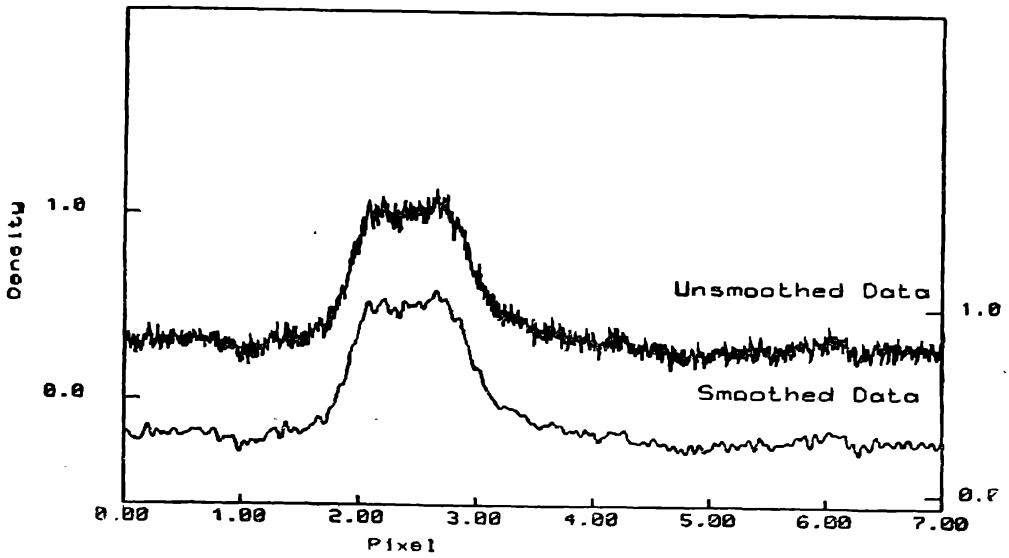

Figure 5. Raw photographic densities of Hα profile in nova LW Ser, and the same data smoothed interactively, using the SMOOTH command with a lowpass filter cut-off frequency of 15 cycles mm^{-1}.

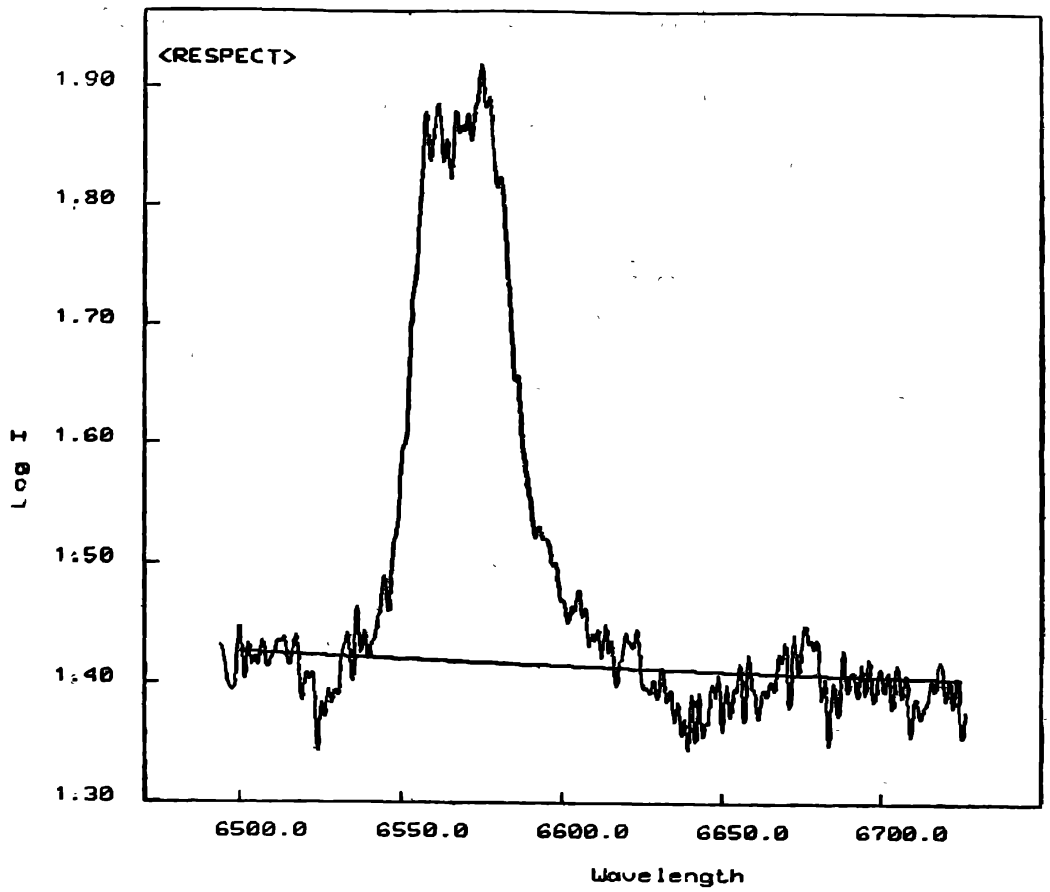

Figure 6. Interactive continuum fitting using the CTMR command. The line at the bottom is a fit to the continuum determined interactively.

LINT converts the density data into logarithmic intensities using the polynomial coefficients of the characteristic curve in Baker-transformed densities. BKGD subtracts the background intensity.

The spectra can be reduced to continuum by using either the CTMR or FREG command. CTMR allows interactive choice of continuum points whereas FREG simply divides the intensities by an extremely-lowpass-filtered spectrum. Figure 6 shows an example of continuum-reduced spectrum using the command CTMR.

5. The scope

The RESPECT software is fully capable of fulfilling the current local needs of reduction of spectrophotometric data. The emphasis is currently on interaction with the data, and it is expected that it will continue to be of service to the novice in astronomical spectrophotometry for a specific detector. The software may not grow to be much bigger than its present size (c. 10^6 bytes excluding the source files), since it is expected that the reduction techniques could be standardized once the familiarity is achieved with digital reductions. Also the capabilities of installing and using larger, more versatile software packages would be achieved with these initial experiments.

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