A VAX USER GUIDE TO **VLINE**
AN INTERACTIVE SPECTROPHOTOMETRIC ANALYSIS PROGRAM

by
GRAHAM HILL

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INDEX

1. INTRODUCTION

VLINE is an interactive program which enables one to measure wavelengths, equivalent widths (EW), line widths (FWHM and/or rotational velocities) in wavelength calibrated rectified or unrectified intensity spectra by simultaneously fitting mixtures of up to 12 Gaussian, Lorentzian, Rotational, or standard (digital) profiles and a linear continuum to selected chunks of spectra. Thus one can analyse double-lined spectroscopic binaries or deconvolve moderately blended features. It is also possible to fix the separation between pairs of unresolved profiles in order to deconvolve more severely blended features or fix the FWHM or depth. Alternatively, one may bypass the profile fitting, measuring only the continuum, and then measure EW by integrating areas between the adopted continuum and the spectrum as defined by 2 cursor placements.

VLINE uses CURFIT (Bevington 1969) to solve a composite function with a maximum of 38 unknowns. CURFIT needs starting estimates and this the user must provide by using the CURSOR option on the GRAPHICS terminal. There are problems with this type of program, notably that of user error. Because of this there is a heavy redundancy at each step to allow one to correct for any oversights. Generally VLINE runs very smoothly but it occasionally fails in the matrix inversion if poor starting values are given.

If one wants to repeat the same sequence of keystrokes on another spectrum, preferably that of the same star, it is possible to record them and a subsequent 'playback' quickly measures the spectrum. This feature may be used with a master file, i.e. a file containing the names of spectra to be processed, to automatically measure a whole series of spectra.

VLINE can be used in two modes.

MODE 1. LINE LIST. Here one uses a list of lines to direct VLINE. Data for each line, if signalled, are brought up on the TEKTRONIX (or GRAPHICS) screen. The amount of data is governed by the 'line width', a datum contained in the LINE LIST FILE along with the rest λ and ion identification.

MODE 2. RECORD. Here one steps through the spectrum record by record beginning at the lowest λ. By default the length of each data record is 901 points, but it can be freely changed. Up to 3000 points can be plotted but the practical limit in terms of plotting and computing time is 901 points.

Used in either of these modes VLINE allows one the choice of freely changing between them provided a line list has been specified. In either mode every line that has been measured is identified on the screen. For routine velocity and/or EW measurement the LINE LIST MODE is useful and fast but for exploratory work the RECORD MODE is naturally better.

Often large blocks of data contain more than 12 lines, the arbitrary limit I've set, and hence only a part of these data can be used. Also if large chunks of continuum, seen to be locally linear, are present

computing time can be reduced by only analysing pieces of the spectrum around each line. These considerations alone govern the measuring structure of VLINE as outlined in the SUMMARY section (3, p. 16-5).

The measuring process is straight forward, but time-consuming, inasmuch as CURFIT requires starting values of the function parameters (mean position λ_o, half-width $\Delta\lambda$, and line depth d) as well as estimates of the (linear) continuum level. These values are directed to VLINE by means of CURSOR placements. A continuum level is set on the first (CL) and last (CR) cursor placements and each line profile is defined by 3 settings (left half-width LH, centre (and depth) CD, and right half-width RH). For one line the order of cursor placements is CL, LH, CD, RH, CR. For more than one line the sequence of measures is CL, (LH, CD, RH), (LH, CD, RH),..., CR. The mean position and half-width values come directly from the encoded X positions. The continuum height and slope is derived from the encoded X positions and the intensity value of the data point nearest the cursor although these intensities can also be defined with the cursor. The line depth is measured with reference to this continuum level and the intensity value of the data point nearest the central cursor measure. The line depth can also be defined by the cursor (see later). Thus the starting values are derived from mixtures of encoded X positions (and perhaps Y positions) and the intensity of the data points nearest the cursor.

CURFIT is remarkably forgiving in that it can tolerate poor starting values. However care must be taken to provide good starting values for weak lines in the wings of strong lines. In this case the continuum for the weak line is essentially that of the profile of the strong line and the initial value of the depth must be encoded from a Y placement of the cursor. Fairly good starting values result in a speedier, and more reliable, convergence in CURFIT.

Once CURFIT has converged the resultant function is graphed through the data so one can gauge the adequacy of the fit. This process results in, for each line, a mean position, depth, FWHM (and perhaps vsini) and a theoretical equivalent width (EW) based on the function parameters and the continuum height. In addition one can choose to integrate both the data and the fitted curve between CURSOR defined bounds and the continuum. Thus three equivalent widths can be generated for each line. Between these three approaches one can safely find a reliable EW even in the face of plate flaws, blended profiles or lines within, or upon, lines.

When one measures from a LINE LIST a radial velocity (RV) can be found immediately for the first measured line in a group. Using this value, wavelength offsets can be calculated for the other lines and a search for coincidences made against the line list. The width of the

'window' used for this comparison is freely variable but the default value is 0.2 A. Thus RVs can be calculated for many measured lines provided the first line measured in each new display is a known one and the others are present in the line list. As the measuring progresses all lines previously measured are identified on the screen with arrows and the LINE INDEX is increased if the expected (current) line has already been measured.

Currently considerable effort is needed to get underway.

a) A plate, including calibrations, must be scanned on the PDS in a manner consistent with that needed for VELMEAS and REDUCE (see the description of SCANN)

b) This output must then be processed by REDUCE into a linearized wavelength file and converted to intensity or rectified files (see Figure 1 page 6).

2. INPUT FILE ARRANGEMENT

2A. General considerations.

VLINE can be used without any input file provided a LINE LIST is not needed. However if a line list is needed then it must be compatible with the STELLAR INPUT FILE used in VELMEAS. The following factors affect the arrangement of lines within the file.

a) To derive a radial velocity one should begin with one or more reliable lines so the wavelength offset with respect to an identifying arrow can be adequately gauged, thus simplifying line identification. Such identification is straight-forward in normal B star spectra but it can become a problem in rich, sharp-lined spectra such as are found in Be shell stars or Am stars.

b) Arrange the lines in order of λ. This will enable a number of lines to be measured simultaneously and will considerably speed the measuring process.

c) Make the width of spectrum to be plotted equivalent to < 901 points. (We only use a screen width of 900 rather than the 1024 because of the extra graphics, labels, etc.)

2B. File FORMAT (F11.3, A1, 1X, A4, 1X, F6.0)

The first variable is the adopted rest λ and the second indicates whether the line is to be measured (blank) or not (asterisk). [By using the asterisk an existing file need not be dismembered to be used]. The next variable is the line identification and the last is the plotting width in Angstroms. This FORMAT will enable the same input files to be used in VELMEAS, VLINE and UVLINE (the IUE reduction program). A sample file is shown in Table 1.

2C. Standard (digital) profiles

You may choose to fit your own profiles to data, particularly if you are dealing with asymmetric profiles or other non-analytic shapes. If you choose to use one then the file must contain a normalized profile as pairs of values (X, intensity) such that X is normalized to FWHM and Y is unit intensity away from the line centre. Part of a sample file for the function $(1 - e^{-x2})$ is

X	Y
-2.5	1.000
-2.0	0.982
-1.5	0.895
-1.0	0.632
-0.5	0.221
0	0.000
+0.5	0.221

etc.

Note that this file does <u>not</u> contain enough resolution in X to be useful since the fitting depends on numerical differentiation and these values would be poorly defined here.

3. VLINE SUMMARY.

A flow chart for VLINE is given in Figure 1. Some of the various program STEPS are also noted. We now briefly discuss these steps.

STEP 1 Select and read appropriate wavelength file (usually an 'R-file' from REDUCE).

STEP 2 Assign a LINE LIST FILE if one is wanting to derive radial velocities.

STEP 3 Assign an OUTPUT FILE if one wants to store the results.

STEP 4 Here data are displayed, edited and fitted with a composite function to yield line positions, line widths and equivalent widths. The full interaction in this step is displayed in Figure 2.

STEP 5 Further line selection, or data block is made here. Parameters involving the amount of data displayed, smoothing, etc. can be altered here as well as I/O files (STEPS 2 and 3).
Alternatively one can EXIT or return to STEP 1.
Each of these STEPS will now be described in greater detail.

TABLE 1. SAMPLE STELLAR FILE*
(FORMAT F11.3, A1, 1X, A4, 1X, F6.0)

3659.423	H 33	50.	3933.664	Ca 2	50.	4366.896	O 2	50
3660.280	H 32	50.	3954.370	N 2	50.	4379.100	N 3	50
3661.221	H 31	50.	3964.727	He 2	50.	4387.928	He 1	50
3662.258	H 30	50.	3968.465	Ca 2	50.	4414.904	O 2	50
3663.405	H 29	50.	3970.075	H 5	50.	4416.975	O 2	50
3664.679	H 28	50.	3994.996	N 2	50.	4437.549	He 1	50
3666.097	H 27	50.	4009.270	He 1	50.	4471.477	He 1	50
3667.684	H 26	50.	4026.140	He 1	50.	4471.507	He 1	50
3669.466	H 25	50.	4026.189	He 1	50.	4481.228	Mg 2	50
3671.478	H 24	50.	4069.794	O 2	50.	4510.906	N 3	50
3673.761	H 23	50.	4072.162	O 2	50.	4514.861	N 3	50
3676.365	H 22	50.	4075.868	O 2	50.	4523.590	N 3	50
3679.355	H 21	50.	4088.862	Si 4	50.	4541.610	He 2	50
3682.810	H 20	50.	4097.330	N 3	50.	4549.550	Fe 2	50
3686.834	H 19	50.	4101.738	HDel	50.	4552.622	Si 2	50
3691.557	H 18	50.	4103.394	N 3	50.	4567.841	Si 2	50
3697.154	H 17	50.	4116.103	Si 4	50.	4574.758	Si 2	50
3703.855	H 16	50.	4119.221	O 2	50.	4583.701	Fe 2	50
3711.973	H 15	50.	4120.812	He 1	50.	4590.974	O 2	50
3721.941	H 14	50.	4128.051	Si 2	50.	4596.178	O 2	50
3734.370	H 11	50.	4130.876	Si 2	50.	4634.145	N 3	50
3750.154	H 10	50.	4143.759	He 1	50.	4638.857	O 2	50
3770.632	H 9	50.	4153.304	O 2	50.	4640.632	N 3	50
3797.900	H 8	50.	4168.970	He 1	50.	4641.811	O b2	50
3819.606	He I	50.	4187.050	C 3	50.	4641.875	N b3	50
3835.386	H 7	50.	4189.788	O 2	50.	4649.141	O 2	50
3853.657	Si 2	50.	4199.830	He 2	50.	4650.844	O 2	50
3856.021	Si 2	50.	4267.160	C 2	50.	4661.635	O 2	50
3862.592	Si 2	50.	4276.050	O 2	50.	4676.234	O 2	50
3867.480	He I	50.	4317.144	O 2	50.	4651.460	C 3	50
3888.648	He I	50.	4319.635	O 2	50.	4685.740	He 2	50
3889.051	H 6	50.	4325.770	O 2	50.	4713.143	He 1	50
3918.977	C 2	50.	4340.466	HGam	50.	4861.327	HBet	50
3920.677	C 2	50.	4349.428	O 2	50.	4921.929	He 1	50
3926.530	He I	50.	4351.270	O 2	50.			

*Numbers begin in column 3. Line identification in column 14. The file has been restructured (3 columns) for illustrative purposes.

Figure 1. VLINE FLOW CHART

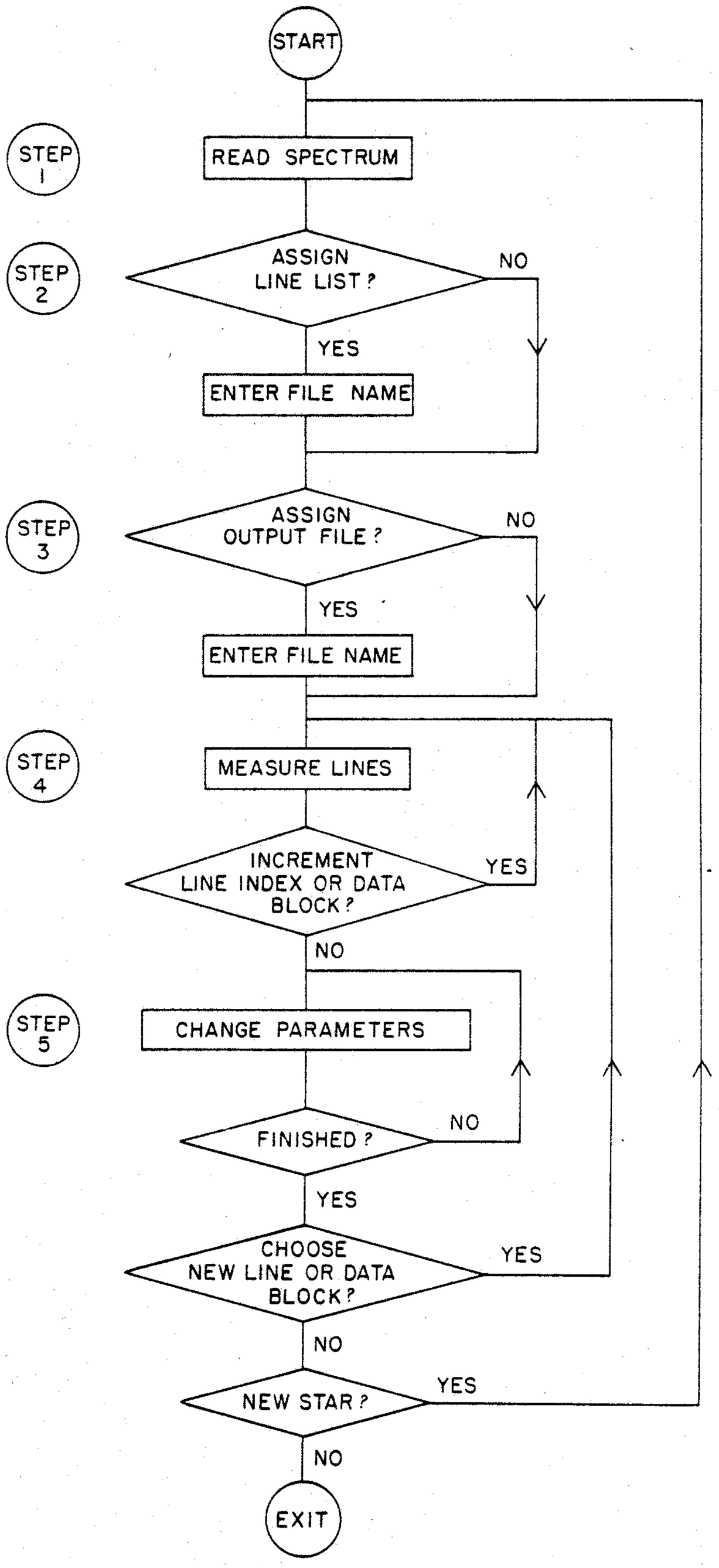
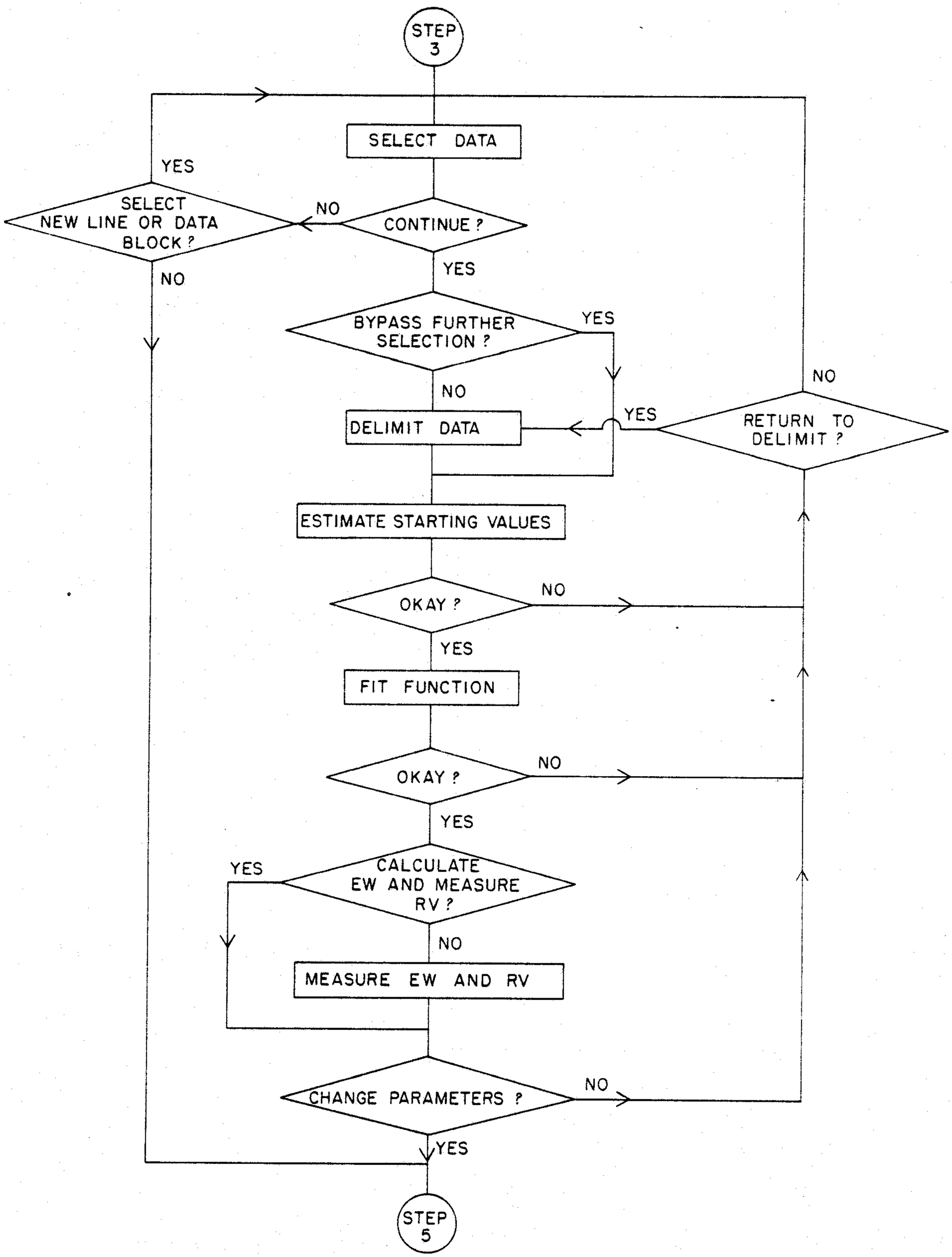


FIGURE 2. STEP 4. FLOW CHART



4. DETAILS OF VLINE

STEP 1 Read a linearized FITS file (W,I or R)

STEP 2 It is possible to record an extensive series of keystrokes in a file called VRECORDR.DAT and play them back later to measure other FITS files. For a consistent set of data this has some obvious benefits. Note that a similar option (using the file RECORD.DAT) is available in VELMEAS (or Option 4 of this manual).

PROMPT: DO YOU WISH TO OPERATE IN THE ROBOT MODE? N = no, R = record P = Playback.

If using the record mode the keystrokes are logged in the file VRECORDR.DAT

REPLY: R to engage the file VRECORDR.DAT

P to 'playback' this file

N to ignore this option.

Note that files produced by VLINE are not compatible with those generated here and hence the "R" after VRECORD. Keystrokes logged by VLINE are recorded in VRECORD.DAT.

Here you must give VLINE a line list if you want radial velocities. The first line should be one that you can readily identify so you can see how the stellar lines are offset from the expected positions.

PROMPT: ARE YOU USING A LINE LIST? Y or N

REPLY If Y you will be prompted again.

PROMPT: ENTER FILE NAME.

STEP 3 Here an OUTPUT file is assigned or changed if you want it.

PROMPT: DO YOU WANT AN OUTPUT FILE? Y = NEW, S = SAME, D = DIFFERENT, N = NO.

REPLY If Y you will be prompted again.

The next prompt will vary depending on whether you are working from a line list.

PROMPT: Skip to 1st record (1), to lambda (W), or status table (S)

REPLY In the line list mode you may go to a particular line by entering #. You will be prompted for a line number 1 to write 1st block (or line) of data to the screen. If you are running in the line mode then the 1st line will be displayed, otherwise the first 901 points will be written.

W to go to a given wavelength and plot 901 points.

Both 1 and W take you to STEP 4.

S directs the program to the status table at STEP 5.

STEP 4 Selection of data and measurement of stellar lines.

When one first enters STEP 4 header information is written which will serve to remind you of the mode (LINE LIST or RECORD) in which VLINE is operating.

LINE LIST header: LINE 3 LAM 3662.258 PTS 301

RECORD header: LAM: LO 3600.000 HI 3650.00 PTS 1001

If you find that VLINE is in the wrong mode an immediate return to STEP 5 can be made to correct the situation. All lines that have previously been measured are indicated by arrows. These arrows are slightly lower than the one which identifies the CURRENT LINE if one is working in the LINE LIST MODE. These arrows are also displayed in STEPS 4.1-4.3. The four program steps within STEP 4 are shown in the flow chart (Figure 2) and are now described in detail.

STEP 4.1 Selection and scaling of the spectrum.

Here one selects part or all of the displayed spectrum. If the spectral features of interest are badly placed with respect to the centre of the screen they can be shifted (<,>) or expanded (X) by these keystrokes. Alternatively one may select part of the display by making two cursor placements with the thumbwheels and the spacebar (set from left to right). The Y (intensity) scale may also be expanded by the use of the commands (^VM). The commands act as switches and don't act until the data are replotted and leave the program at the current cursor position.

PROMPT: ^VM$#QNESOB<X>@PW

REPLY We now describe the keystrokes in turn. Note that SOBNQ all have the same meaning in Step 4 so we describe these 1st.

S Skips to the current status table (Step 5).

O Brings next line or record to the screen.

B Returns to the start of Step 4 (our current step, Step 4.1)

W Prompts for a new starting wavelength.

E Take all of the displayed data and skip to profile fitting at Step 4.3.

N Leaves the program at the next step if an N is struck on the 1st cursor.

Q Encodes the X-cursor position and writes λ onto the screen. Q must be used prior to any other operation, and may be repeated.

Change Y scale (Step 4.1 and 4.2)

^ Set y-cursor to desired maximum intensity.

V Set y-cursor to desired minimum intensity.

M Switch from plotting max-zero to max-min or vice versa.

Replot screen (Step 4.1 and 4.2)

$ Replot with ^VM changes.

Replot original screen with default values.

< Moves the spectrum to the left (to long λ). The amount of the shift is NFRAC (see Status Table Step 5). The default value is 5, such that a record of n pts would be moved n/5 data points to longer λ.

> Moves the spectrum n/5 data points to the right (to shorter λ)

X The display is increased by 2n/5 data points.

@ Will initiate the fixing of parameters to be done at Step 4.3.1. The cursor is not encoded and the program stays at the start of 4.1 .

P Will enable you to form a standard profile from the data currently displayed (see Appendix 1). To use this option effectively, since it does involve forming a standard profile of one line, you must isolate the profile by using the Status Table and then strike P.

STEP 4.2 Delimiting the Spectrum

Here we may select discontinuous pieces of data. The selection is made by successive pairs of cursor settings (from left to right). The end of the selection is signalled by an E on the last (rightmost) setting. Note that if you wanted to fit a single profile to the data this profile would have to be isolated by the pairs of cursor settings as well as enough continuum to provide a good fit. The Y scale may also be altered.

PROMPT: ^VM$# BQEW

REPLY B to return to previous step.

Q to encode a wavelength

E to end the pairs of setting.

^ Set y-cursor to desired maximum intensity.

V Set y-cursor to desired minimum intensity.

M Switch from plotting max-zero to max-min or vice versa.

$ Replot with ^VM changes.

Replot original screen with default values.

W Prompts for a new starting wavelength.

STEP 4.3 Establishing starting values. Here we measure the starting values by using the X-cursor, and occasionally the Y-cursor. We can also initiate the fixed parameter mode here if it has not been done at Step 4.1. These starting measures are made by making 2 continuum settings with the X-cursor (1st and last placements in the sequence) and 3 settings for each profile in order to define the FWHM, mean position and line depth. As an example the complete settings for two profiles using the space bar are: left continuum (LC), left FWHM (LH), center (C), right FWHM (RH), left FWHM (LH), center (C), right FWHM (RH), right continuum (RC). Normally the y (intensity) value is taken to be that y datum nearest the X-cursor but it can be measured by adjusting the Y-cursor and striking the T key. The only y values that are used are in the continuum and line centre measures. The type of profile to be used in the fit is governed by the key that is struck on either the left FWHM setting or the central setting. The end of the settings (rightmost continuum placement) is signalled by an E key or by a T if the continuum height is being fixed. Ending the data entries in this way removes the necessity

for counting the number of placements. A sample sequence for a Gaussian and Lorentzian with a central Gaussian line depth defined by the Y-cursor would be:
space bar (LC), G (LH), T(C), space bar (RH),
space bar (LH), L(C), space bar (RH), space bar (RC).
Prior to making a sequence of measures the # and type of profiles to be fitted may be signalled leaving the program at the beginning of this Step (4.3). For example: G, L or R struck at the beginning sets the # of lines to be fitted at one and lets the program expect a Gaussian (G), Lorentzian (L) or rotational profile (R). A D sets the profile number to 2 and an H sets it to the default value of 12 (# of unknown 12•3+2 = 38).

PROMPT: FIT GLR45CQMKDHVSOBNTFEW@ GAUS N38

REPLY @ Initiates fixed parameter mode. Then begin the cursor placements.

Placement 1. Left-hand continuum (can accept nearest Y datum by hitting the space bar or encode the y-cursor height by striking the T key).

Placement 2. Set on left-hand side of profile near half-intensity point. Can define the profile type here by entering G, L, R, 4 = one standard profile, 5 = different standard profile. When 4 or 5 is struck for the 1st time the user is prompted for a profile file name.

Placement 3. Set on minimum or maximum profile. Identify the profile type if not encoding the Y cursor with the T key.

Placement 4. Set on right side of profile at half-intensity point.

Placement 5. If more profiles are to be defined repeat placements 2-4, otherwise make the final placement now. This (final) placement is signified by entering an E, or a T if the continuum height is to be defined by a Y-cursor setting. Ending the sequence of entries with the E or T removes the necessity for counting the entries. One must remember the order of the settings; e.g. when using a line list the 1st line measured must be the current, or expected, line otherwise the RV will be wrong and incorrect line identifications, and hence RV's, derived. Also (obviously) the order of the lines measured here govern the order of th EW measures and the tabulated results. If this order is forsaken (and you govern it) a wrong EW will be associated with a measured line position. Because it is easy to err with all of

these settings one may escape to the 2 previous steps (4.1 and 4.2) by shift to the Status Table in Step 5 by entering S. In the special case where the continuum height is to be fixed (one line only) the number of settings must be changed to 3 by use of the C key followed by 3 + Return. An H key sets NTERMS to the maximum value 38. As before (STEPS 4.1, 4.2) Q encodes the X-cursor and writes the wavelength on the screen before returning to the first setting. Each of these keystrokes (G, L, R, D, C, H, Q) when initiated on the first (left-most continuum) setting returns VLINE to wait for the first setting again. Be cautious here. If you hear a bell VLINE has accepted the setting and you must either recognize that you have made an error or move on to the first line measure. The last setting, either because you have reached NTERMS or have ended the settings with an E, is indicated by two bell rings and now CURFIT is solving the problem.

Three keystrokes/line are quite a lot but these can be considerably reduced if the spectral lines are more or less the same width. Under these circumstances once the starting half-width has been established only one setting (centre, depth (d)) need be made/line. To invoke this enter a W on the rightmost side of the first measured line (4th setting). VLINE then uses this half-width as the starting value for all subsequent measures. When W has been entered VLINE is immediately reinitialized to the beginning of STEP 4.3 and a W will appear with the PROMPT (e.g. GAUS N 38W) on the upper right-hand side of the screen. Note that this prompt appears every time a line profile type is entered or the number of terms changed or the W option invoked. Once reset the user need make only one centre setting/line plus the 2 continuum settings. To revert to the normal (3 settings/line) mode enter a V on the first continuum setting and begin again at STEP 4.3.

If, while making the settings which involve an intensity (Y) value - usually VLINE accepts the intensity value nearest the cursor - you feel that the intensity level is poor (plate flaw, line within a line) the intensity level and mean position can be set by using both cursors simultaneously and entering a T. Remember that the depth starting values are taken with reference to the continuum level. Thus a line in the wing of another line will have a larger apparent depth than the actual one if you

simply accept the intensity value nearest the CURSOR. In this case the horizontal CURSOR should be set above the apparent line centre and encoded with the T command. A potential difficulty can arise between the T command and the one setting/line (W) option when a line profile type is different from the default type. One cannot use two keystrokes to encode the Y position and the new profile type. Because CURFIT is fairly forgiving one can 'chance it' and forego the T option here, leaving VLINE with a poor starting value of the line depth.

You can fix the continuum height with the T command in pathological situations involving one line. Here NTERMS must be changed to 3 at the beginning of this STEP (4.3) by entering C and then 3 + RETURN. Make the normal 5 settings but use the T command to fix the continuum level at each end.

Fixing Velocity Separation

If you know the separation, in Angstroms or km s^{-1}, between two lines then this can be a help in stabilizing a CURFIT solution for two severely blended lines (but it still may not help). Here one enters F on the centre setting of the line that you wish to fix with respect to the other. VLINE then waits for you to enter a (signed) floating point number; +ve if you are anchoring this line to the previous line, -ve if anchored to the next line. This entry will be assumed as an RV if |ENTRY|>10., otherwise VLINE will consider it a wavelength. I hope that this option will help to deconvolve poorly resolved features which however contain known differential λ information. Note that only one pair of lines can be treated like this in a fitting sequence of < 12 lines. The indexing problems are horrendous here and it is just not worth the effort, both from a programming and user standpoint, to generalize this feature.

The remaining options in STEP 4.3, the M and K commands are ones in which λ measures are made (and recorded) across the screen using the X-cursor alone, i.e. there is no recourse to any fitting procedure. In describing how this option works we are anticipating a similar description later (Note on Radial Velocities). The demands are different if one is operating in the RECORD or the LINE LIST modes. The least complicated is the former.

RECORD MODE: Make M or K setting. If K there will be no prompt.

PROMPT: ENTER COMMENT ... 30 BYTES MAX

REPLY. Enter appropriate comment. The measuring will continue as

long as you continue to enter M + COMMENT or K alone. There is no restriction on the number of lines measured and commented in this way. Note: At the end of each measure VLINE remains at the beginning of this step (STEP 4.3).

LINE LIST MODE: Here the order of measurement is important since in this mode a radial velocity (RV) is calculated based on the assumption that the first line measured is the same one identified in the header to STEP 4.1 (and by the arrow). Thereafter any further M keystroke will prompt VLINE to attempt a line identification based on this RV. The corrected wavelength is checked against all the lines in the LINE LIST. An identification and RV is assigned if this comparison is within 0.2 A (the default option). This limit can be changed in STEP 5. This operation will yield a messy screen but will enable the user to measure approximate positions and RV's for many lines. Note: At the end of each measure VLINE remains at the beginning of this step (STEP 4.3).

STEP 4.3.1 Fixing Parameters. If you had entered an @ at Step 4.1 or 4.3 you will now have a chance to fix the parameter(s) of your choice. The screen will erase and the current starting values displayed. You will now be prompted to enter the index and value of those parameters to be fixed. If one parameter is to be fixed to another (you don't know the value but you want to tie them to each other) enter a -ve index. You will then be prompted for the index of this other parameter. The value(s) in this case will be determined by the program. These entries are terminated by a zero. The screen then clears with the data plotted anew and the solution graphed through the data.

Fixing continuum Only. Here one makes 2 cursor settings, CL and CR. End with an E on the 2nd setting. A straight line will be fitted to, and drawn through, all the data delimited in Step 4.2 Note: If you have accepted all of the data in Step 4.2 then the continuum will be fitted to all of the data. Remember select just the data you want to fit in Step 4.2.

NOTE ON RADIAL VELOCITIES

Radial velocities (RV) can only be evaluated if one is working from LINE LIST. To effect proper identifications for all the lines measured in this STEP the first line measured must be that identified in the header and by the arrow(s) in STEP 4.1 and 4.2. In a rich sharp-lined spectrum this identification may not be straight forward so the line list should be headed by a

line, or lines, that you feel you can identify. After that offset is clear in your mind you will probably be able to correctly identify subsequent 'first' lines. This is the identical approach one uses when measuring on ARCTURUS. [Provided you edited the output later the M command could be used to explore these identifications since it writes an RV on the screen]. Once the first line is measured a wavelength offset is applied to each of the remaining lines in the group, actually $\Delta\lambda = \Delta\lambda_1 \times \lambda/\lambda_1$, and a search made amid the line list for other identifications. The 'window', in Angstroms, used for this identification can be freely set at STEP 5 and the default value is 0.2A. After the final setting is signalled by an 'E' keystroke, CURFIT solves for the best values of λ_o, $\Delta\lambda$, d, h and s and graphs this fit through the observations.

Option summary

The various options just described are now summarized. While it is not easy to uniquely categorize the options available, they are summarized below in three broad groups.

i) Branching Options. These can be invoked anytime within STEP 4.3 to move the operation elsewhere.

ii) Initial Options. These options must be invoked at the start of the STEP and will leave the operation again at the start of STEP 4.3.

iii) Run-time Options. These instruct VLINE as the starting values are being entered with the cursor.

4B. OPTION SUMMARY FOR STEP 4.

STEP 4.1 STEP 4.1 (^VM$#PNESOWB<X>@P) Selection of Spectrum

BRANCHING OPTIONS (use anytime)

B Returns to beginning of STEP 4.1.
S Skips to the CURRENT STATUS TABLE in STEP 5.
O Brings either the next LINE or RECORD to STEP 4.1.
W Prompts for a new starting wavelength.

INITIAL OPTIONS (zeroth setting)

N Skips to next step (STEP 4.2)
E Skips to third step (STEP 4.3)
^ Set y-cursor to upper intensity limit.
V Set y-cursor to lower intensity limit.
M Switch from plotting max-zero to max-min or vice versa.
$ Replot current screen.
# Replot with default parameters.
< Moves displayed spectrum to left (to increased wavelength by an amount NPTS/NFRAC.
X Expands screen image by 2X(NPTS/NFRAC).
> Moves displayed spectrum to right (to decreased wavelength) by an amount NPTS/NFRAC.
Q Encodes λ from X-CURSOR.
@ Initiates fixed parameter mode.

STEP 4.2 STEP 4.2 (^VM$#BQEW) Delimit spectrum

^ Set y-cursor to desired maximum intensity.
V Set y-cursor to desired minimum intensity.
M Switch from plotting max-zero to max-min or vice versa.
$ Replot with ^VM changes.
# Replot original screen with default values.
B Returns to beginning of Step 4.2.
Q Encodes λ from x-cursor.
W Prompts for a new starting wavelength.
E Ends the pairs of settings.

STEP 4.3

STEP 4.3 Starting values.

BRANCHING OPERATIONS (use anytime)

S Skips to the CURRENT STATUS TABLE in STEP 5.
O Brings either the next line or record to STEP 4.1
N Returns to STEP 4.2
B Returns to STEP 4.1 without changing the current line or RECORD.
P Form a standard profile (Appendix 1)

INITIAL OPTIONS (zeroth setting)

G One Gaussian profile (NTERMS = 5)
L One Lorentzian profile (NTERMS = 5)
R One Rotational profile (NTERMS = 5)
D Two line profiles (NTERMS = 8)
C + number + RETURN. Changes the number of terms.
H Twelve profiles (NTERMS = 38)
V Resets VLINE to 3 settings/line (see below)
Q Encodes X-CURSOR to yield λ.
M Encodes X-CURSOR to measure and record λ.
Will also measure RV.
K Means same as M except COMMENT PROMPT is bypassed.
@ Fix parameters at end of Step 4.3.

RUN-TIME OPTIONS

G Gaussian profile (2nd and 3rd line setting)
L Lorentzian profile (2nd and 3rd line setting)
R Rotational profile (2nd and 3rd line setting)
T Encodes X and Y cursor (continuum and line centre only)
W Uses the width of the first measured line for all subsequent entries until negated by entering a V (very first setting). W must be entered on fourth setting.
F + number + RETURN. Fixes separation between two lines (Angstroms or km s^{-1})
E Ends the sequence of entries.

STEP 4.4 Confirming the fit

PROMPT: FIT OK? LNBPWOS^

REPLY. When VLINE has optimized the fit the calculated curve is plotted through the data and each mean position drawn on the bottom of the screen. Now you must decide whether the fit is satisfactory and, if so, whether the EW should be measured by additional CURSOR placements (W) or to simply rely on those computed from the derived function parameters (L). If the fit is not satisfactory it can be abandoned (S,O) or a new solution attempted from STEP 4.1 (B) or STEP 4.2 (N). If the fit has failed (divide by zero in CURFIT or square-root of a -ve number) a bell will ring and a message ***SOLUTION FAILED*** is written on the TEKTRONIX. You must branch using the S, O, N, B command now. The option summary follows.

STEP 4.4 confirming the Fit

OPTIONS

S	Skips to the CURRENT STATUS TABLE in STEP 5.
O	(letter) Brings either the next LINE OR RECORD to STEP 4.1
N	Returns to STEP 4.2.
B	Returns to STEP 4.1
P	Prints details of the fit (λ, intensity, fit, O-C) and skips to next STEP 4.5
W	Skips to next STEP 4.5.
L	Immediately records λ_o, $\Delta\lambda$, d, EW and profile type.
^	Returns to STEP 4.3 to begin the fit again.

STEP 4.5 Measuring and/or calculating equivalent width

PROMPT: EW TJKRNBOS

REPLY. As mentioned in the Introduction an EW can be measured in three ways.

i) Calculate the EW of the area of a single line, normalized to the continuum, from the parameters of the fit.

ii) Measure the EW between the data, continuum and two cursor placements. Note that under these circumstances some sort of interpolation formula or smoothing polynomial must be put through the data. The order (NT) of this polynomial is 2 (linear) by default.

iii) Measure the EW between the fitted function, continuum and two cursor placements. The same order smoothing polynomial is used here.

Note: If you have only defined the continuum, bypassing the line profile fitting, then you may make EW measures with 2 cursor placements. Areas will be measured between the data, continuum, and the wavelengths defined by the cursors. Repeat measures may be made by entering an R on one cursor setting. The comment may be avoided by entering a K once/measurement. Negative areas are those measured above the continuum (emission lines). The wavelength written is the mean of the 2 cursor placements. End these with a J or an E.

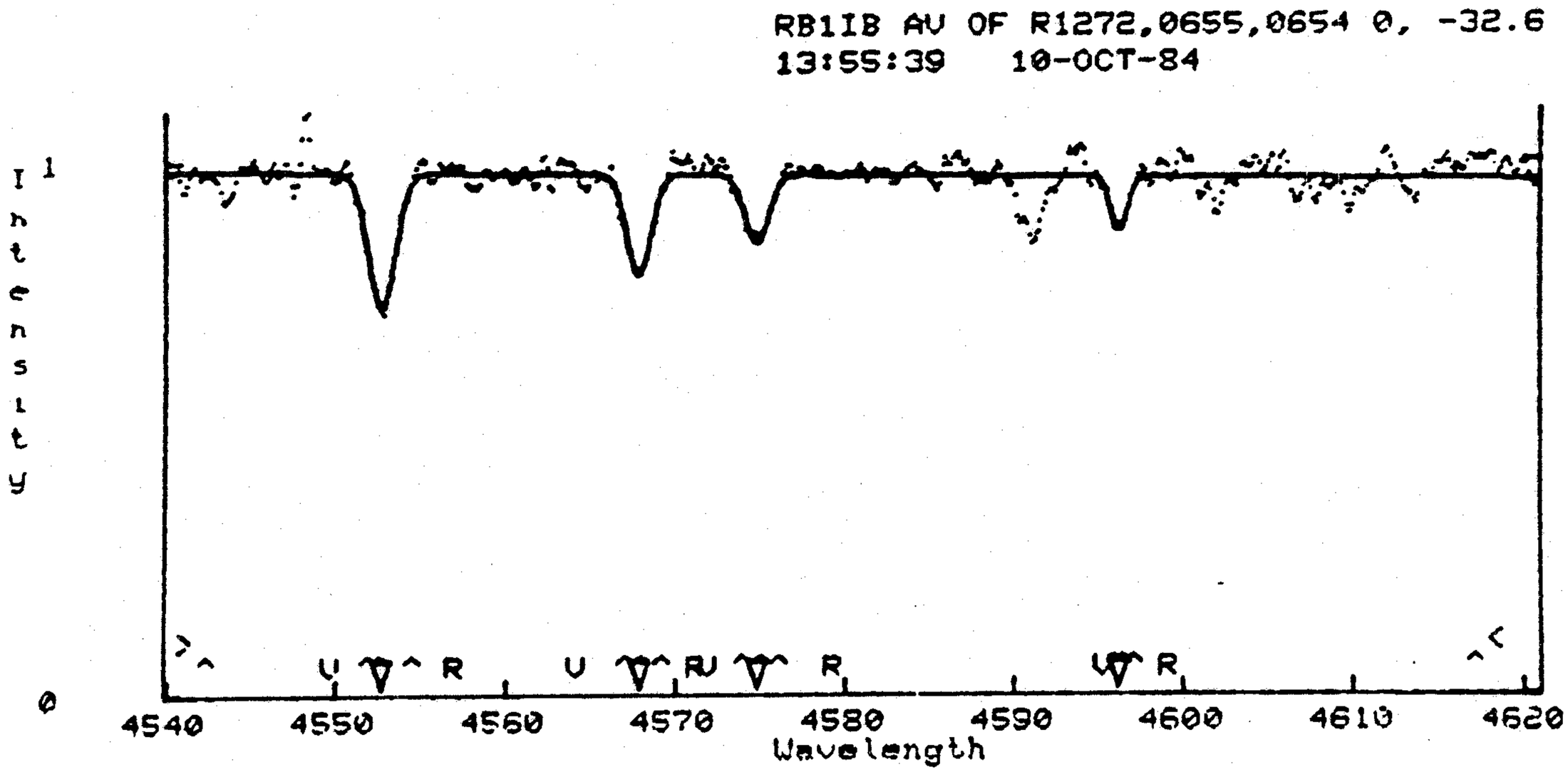
The USER may have problems seeing the differences between i) and iii). Remember that i) is the area of a single line even if the spectrum has been fitted with a composite function whereas iii) is the area of the composite line if there is more than one line comprising a spectral feature. In the case where only one line has been fitted all three EW's will give the same answer. If two partially blended lines have been fitted then the EW's from ii) and iii) will be identical and will differ from i) for each line as it is measured. Note that this measurement must take place in the same order as the lines were measured otherwise the measured EW (ii, iii) will differ from the mean position and the calculated EW (i).

Make two CURSOR placements to define the width over which the area will be measured. After the second placement the results are written onto the screen (see Figure 3) and you are asked to 'ENTER COMMENT' (N.B. 30 characters is maximum length). If you are satisfied with the fit this invitation can be bypassed by using a K (=OK) on the second of the first two CURSOR placements (anticipate a little). The measure can be repeated if an R has been entered on either setting. Alternatively if you are faced with a poor line, or are unhappy with the fit to it, the measure can be rejected, i.e. not recorded, by entering a J on the first or second keystroke.

If the continuum is poorly placed a new continuum position can be defined by using the Y-cursor on each cursor placements and entering T. Here both the X and Y positions will be encoded. The EW of a single line (i, above) will be in error but EW (ii and iii) will be adjusted to this continuum. The subsequent step (STEP 4.5) can be bypassed if one remembers to enter an N, B, O or S on any one of the cursor settings of the group. These commands have the same meaning as given previously. If you do not branch automatically in this way you will be at STEP 4.6 at the end of the EW measures.

Figure 3. Showing fit and results.

```
DE BQE;FIT GLR4SOQMKDHVSOENTFEW@K?LNEPWOS^; WEW TJKRNBOS
                                                    Gaus N 38

  #    Lam       err      RV     EW 0   EW 1  D fit   FWHM          Comment
     4552.520  0.039           489.7  506.3   0.26   1.85  Com?  OK
     4567.717  0.051           320.3  342.4   0.19   1.69  Com?  OK
     4574.682  0.078           175.7  228.4   0.13   1.67  Com?  OK
     4596.176  0.078           128.3  132.4   0.10   1.20  Com?  OK
```



STEP 4.5 EW MEASUREMENT

RUN-TIME OPTIONS

R Repeat measurement on current line (enter on either setting)
J Ignore current line in profile fitting mode (either setting) or end non-profile fitting EW measures.
K Bypass COMMENT entry (second setting)
T Measure continuum with Y cursor (both settings)
E End EW measures in non-profile (NTERMS=2) mode.

BRANCHING OPTIONS

These options can be invoked anytime but will only be initiated at the end of the measurements.

S Skips to the CURRENT STATUS TABLE in STEP 5.
O Brings either the next LINE or RECORD to STEP 4.1
N Returns to STEP 4.2.
B Returns to STEP 4.1 without changing the current LINE or RECORD.

STEP 4.6 Choice of next STEP

S Skips to the CURRENT STATUS TABLE in STEP 5.
O Brings either the next LINE or RECORD to STEP 4.1.
N Returns to STEP 4.2.
B Returns to STEP 4.1 without changing the current LINE or RECORD.
W Go to specific starting wavelength.
I Go to specific line (if line list is being used).
4,5 Will enable new standard profiles to be defined later, leaving you still at this step. Note, this does not mean form new standard profiles.

STEP 5 Current measurement status and options.

Here the CURRENT STATUS of the measurement and the measuring parameters is displayed in either of two tables, depending on whether the mode is LINE LIST or RECORD. Examples of these tables are shown in Figures 4 and 5. As well as giving details of the parameter values and the code for changing them these tables show how the I/O (Input and Output Files) can be altered. The codes (enclosed in parentheses) are consistent with the OPTIONS: WL, WD, ... given at the bottom of the screen. To change the line number for example in the LINE LIST MODE one enters LI (+RETURN), after which one is prompted to ENTER VALUE. VLINE accepts these entries until the sequence is ended in one of a number of ways.. Normally

this sequence of entries is halted by entering EN (end) after which VLINE moves to STEP 4.1. To avoid these extra keystrokes I have adopted the procedure of automatically branching to STEP 4.1 when LI (line number) or WL (wavelength) entries have been completed. This requires the USER to change other parameters or I/O before entering LI or WL. Automatic branching to STEP 4.1 also occurs when NL (next line), CL (current line), NR (next record), and CR(current record) is entered. When NS (next star) VLINE branches to STEP 1 automatically and subsequently prompts you for I/O (stellar file and output file) information. A list, and description, of the various options is now given.

WAVELENGTH OPTIONS

LI (LINE LIST) Line number. Useful only when a LINE LIST is being used. After changing this VLINE goes immediately to STEP 4.

WL (RECORD) Wavelength of the beginning of the screen display. After entry VLINE moves immediately to STEP 4.

WD (RECORD) Wavelength range governing the screen plotting. In the LINE LIST mode this datum comes from the STELLAR INPUT FILE and the value cannot be overridden. In the RECORD mode WD can be freely changed although one would not want the number of points (NP see later) to be increased to large values (>901 for example). Note that NP = WD/$\Delta\lambda$+1 where $\Delta\lambda$ is the wavelength step between data points. If WD is changed NP is automatically altered. For the usual spacing (0.05 A) and number of data points (901) the practical limit to WD is 45 A. The maximum number of data points for this analysis has been arbitrarily set at 3000.

XL (LINE) This is the wavelength window within which a line identification can be made. The default value is 0.2 A. Remember that in entering STEP 4 only one line is positively identified. The remainder must be inferred from the radial velocity of this known line, the wavelengths in the line list and this window. Once other lines have been identified a radial velocity can be calculated.

PROFILE OPTIONS

IP Indicates the default profile type. 1 = Gaussian, 2 = Lorentzian and 3 = Rotational. If the bulk of the profiles are for example rotationally broadened it is sensible to set IP = 3. The default values is initially 1 = Gaussian.

BE Limb darkening value for fitting a rotational profile. Default value is 0.6.

DATA OPTIONS

NL Directs VLINE to bring the next line onto the screen. If you had been working in the RECORD MODE NL would bring the next line after that indicated by the LAST LINE entry in Figure 5. The NL command will be ignored if no LINE LIST has been specified.

CL Repeats current line.

NR Directs VLINE to bring the next record up onto the screen. If you had currently been working from a LINE LIST the starting λ would be that given as CURRENT LAM in Figure 5 and the amount of data given by the RANGE in the same Figure.

CR Repeats current record.

SM is a smoothing parameter. For 1 point smoothing SM = 0, 3 point SM = 1 and 9 point SM = 2,...

NT is the order of the smoothing polynomial fitted through the data and computed function when the areas are being integrated (INTEG from Bevington is used). The default value is 2 (linear interpolation).

DISPLAY OPTIONS

NP is the number of points displayed and is obviously related to WD (WAVELENGTH OPTION above) such that WD = (NP -1)$\Delta\lambda$. If NP is altered WD is automatically changed.

NF The quantity NP/NF gives the number of points the screen image will be offset if the 'shift right' (>) or 'shift left' (<) commands are used in STEP 4.1. The default value is 5 which means that for a 901 point display the image will be shifted 180 points under the shift command. If the expand command (X) is used then the number of points is augmented by 2 x NP/NF (360 points in the above example).

HT governs the vertical scaling of the display. The scale is given by HT/(1.2 X CURRENT MAX).

PLAYBACK AND RECORD OPTIONS

RE Switches on the record mode so that keystrokes are stored in VRECORDR.DAT.

PL Plays back the keystrokes in VRECORDR.DAT.

END CURRENT OPTION

NS Will close the OUTPUT FILE (if open) and skip to the OPERATIONAL OPTIONS Table.

EX same function as NS above.

I/O OPTIONS

ST enables a STELLAR FILE to be closed or opened.

OU enables an OUTPUT FILE to be closed or opened.

NB. When ST or OU are entered VLINE branches, to PROMPT the USER for the appropriate file names.

BRANCHING OPTIONS

LI Line number

WL starting wavelength

NL next line

CL current line

NR next record

CR current record

NS return to OPERATIONAL OPTIONS Table

EX return to OPERATIONAL OPTIONS Table.

4A. COMMENT

VLINE appears rather complex but once you are familiar with its use your opinion may change. The most important point to remember is that it is not designed for the rapid analysis of a stellar spectrum. It cannot be for two reasons. i) There are too many keystrokes and ii) the fitting process is governed by the speed of the VAX, which is not a fast machine. When settling down to measure make sure that you have a line list at hand and that you document what you do.

Figure 4. Current Status Table - LINE LIST mode.

```
                      ------Current Status------  Mode: Line list
Header: RB1IB AU OF R1272,0655.0654 0, -32.6
Wavelength: Current lam  3954.370
            Range    135.000 (WD)
            Line #     1     (LI)
            D(iam) line ident (Note: 1A=70km/s)    0.20 (XL)
Profile: default profile type; 1=G,2=L,3=R  ** (IP)
         Limb darkening   0.60 (BE)
Data: Next line       (NL)
      Current line      (CL)
      Smoothing  0=1 pt,1=3 pt,2=9 pt,...    0 (SM)
      Max dat value       1.091
      Current max         1.091
      Order of area smoothing poly  2 (NT)
Display: # pts plotted     901 (NP)
         Fraction of these the screen can be shifted (1/entry)    5 (NF)
         Screen height (max=700)    400. (HT)
Disk: Read in new data (NS)
      Exit from VLINE (EX)
I/O files: Stellar line list          Yes (ST)
           Output file                No  (OU)
Stellar line file name is BSTAR.STR
Options: WL,WD,LI,XL,IP,BE,SM,NT,NP,NF,HT:Exit=EX,End entries=EN
Enter two letters--end with EN,NL,CL,NS,EX,ST,OU
```

Figure 5. Current Status Table - RECORD MODE

```
                    -------Current Status------  Mode: record
Header: RB1IB AV OF R1272,0655,0654 0, -32.6
Wavelength: low   4499.000 (WL)
            High  4634.000
            Range  135.000 (WD)
Profile: default profile type; 1=G,2=L,3=R  G (IP)
         Limb darkening   0.60 (BE)
Data: Current record       (CR)
      Next record      (NR)
      Smoothing  0=1 pt,1=3 pt,2=9 pt,...  0 (SM)
      Max data value      1.091
      Current max      1.091
      Order of area smoothing poly  2 (NT)
Record keystrokes (Memorize or ROBOT mode) No  (RE)
Playback keystrokes (ROBOT mode) No  (PL)
Display: # pts plotted    901 (NP)
         Fraction of these the screen can be shifted (1/entry)    5 (NF)
         Screen height (max=700)    400. (HT)
Disk: Read in new data (NS)
      Exit from VLINE (EX)
I/O files: Stellar line list        No  (ST)
           Output file              No  (OU)
Options: WL,WD,IP,BE,SM,NT,NP,NF,HT:Exit=EX,End entries=EN
Enter two letters--end with EN,CR,NR,NS,EX,ST,OU
```

4B. OPTION SUMMARY FOR STEP 4.

STEP 4.1 STEP 4.1 (EX^PNESOB<X>@P) Selection of Spectrum

BRANCHING OPTIONS (use anytime)

B	Returns to beginning of STEP 4.1.
S	Skips to the CURRENT STATUS TABLE in STEP 5.
O	Brings either the next LINE or RECORD to STEP 4.1.

INITIAL OPTIONS (zeroth setting)

N	Skips to next step (STEP 4.2)
E	Skips to third step (STEP 4.3)
<	Moves displayed spectrum to left (to increased wavelength by an amount NPTS/NFRAC.
X	Expands screen image by 2X(NPTS/NFRAC).
>	Moves displayed spectrum to right (to decreased wavelength) by an amount NPTS/NFRAC.
Q	Encodes λ from X-CURSOR.
@	Initiates fixed parameter mode.
^	Enables a small area to be expanded.

RUN-TIME OPTIONS

E	Skips to STEP 4.3 when used on final setting in final pair.

STEP 4.3 STEP 4.3 (FIT GLR45CQMKDHVSOBNTFEW@) Starting Values

BRANCHING OPTIONS (use anytime)

S	Skips to the CURRENT STATUS TABLE in STEP 5.
O	Brings either the next LINE or RECORD to STEP 4.1.
N	Returns to STEP 4.2.
B	Returns to STEP 4.1 without changing the current LINE or RECORD.

INITIAL OPTIONS (zeroth setting)

G	One Gaussian profile (NTERMS = 5)
L	One Lorentzian profile (NTERMS = 5)
R	One Rotational profile (NTERMS = 5)
D	Two line profiles (NTERMS = 8)
C + number + RETURN.	Changes the number of terms.
H	Twelve profiles (NTERMS = 38)
V	Resets VLINE to 3 settings/line (see below)
Q	Encodes X-CURSOR to yield λ.
M	Encodes X-CURSOR to measure and record λ. Will also measure RV.
K	Means same as M except COMMENT PROMPT is bypassed.
@	Initiates fixed parameter mode.

RUN-TIME OPTIONS

G	Gaussian profile (2nd and 3rd line setting)
L	Lorentzian profile (2nd and 3rd line setting)
R	Rotational profile (2nd and 3rd line setting)
4,5	Selects one or other standard profile
T	Enclodes X and Y cursor (continuum and line centre only)
W	Uses the width of the <u>first</u> measured line for all subsequent entries until negated by entering a V (very first setting). W <u>must</u> be entered on <u>fourth</u> setting.
F+	number + RETURN. Fixes separation between two lines (Angstrom or km s^{-1}).
E	Ends the sequence of entries.

STEP 4.4

STEP 4.4. (FIT OK? LNBPWOS^) Confirming the Branching Options

BRANCHING OPTIONS

S	Skips to the CURRENT STATUS TABLE IN STEP 5.
O	(letter) Brings either the next LINE or RECORD to STEP 4.1
N	Returns to STEP 4.2
B	Returns to STEP 4.1
P	Prints details of the fit (λ, intensity, fit, O-C) and skips to the next STEP 4.5
W	Skips to next STEP 4.5
L	Record λ_o, $\Delta\lambda$, d, EW and profile type.
^	Returns to STEP 4.3 to begin the fit again.

STEP 4.5

STEP 4.5 (EW TJKRNBOS) EW Measurement

RUN TIME OPTIONS

R	Repeat measurement on current line (center on either setting)
J	Ignore current line (either setting)
K	Bypass COMMENT entry (second setting)
T	Measure continuum with Y cursor (both settings)

BRANCHING OPTIONS

These options can be invoked anytime but will only be initiated at the end of the measurements.

S	Skips to the CURRENT STATUS TABLE in STEP 5.
O	Brings either the next LINE or RECORD to STEP 4.1.
N	Returns to STEP 4.2.
B	Returns to STEP 4.1 without changing the current LINE or RECORD.

STEP 4.6 STEP 4.6 (WHAT NOW? SONB45WI) Choice of next STEP

S Skips to CURRENT STATUS TABLE in STEP 5.
O Brings either the next LINE or RECORD to STEP 4.1.
N Returns to STEP 4.2.
B Returns to STEP 4.1 without changing the current LINE or RECORD.
W Go to specific λ.
I Go to specific line (if in line list mode).
4,5 Redefine new standard profiles (not form new standard profiles).

4C. OPTION SUMMARY FOR STEP 5.

LI*	Line number
WL*	Beginning λ
WD	Wavelength range
XL	Wavelength window
IP	Default profile type (1=G, 2=L, 3=R)
BE	Limb darkening (default value is 0.6)
NL*	Next line
CL*	Current line
NR*	Next record
CR*	Current record
SM	Smoothing (0 = 1 pt, 1 = 3 pt, 2 = 9 pt, ...)
NT	Order of smoothing polynomial for EW (2 = linear)
NP	Number of points
NF	Display shifting and expanding fraction
HT	Screen height
NS*	Skip to OPERATIONAL OPTIONS Table.
EX*	Skip to OPERATIONAL OPTIONS Table.
ST	Change Stellar File
OU	Change Output File
EN*	End current entries

*Automatic branching options.

5. OUTPUT DESCRIPTION

5A. TEKTRONIX DISPLAY

i) When an M command is used to measure RV (see Figure 6) the line number, λ and RV are written on the screen.

ii) When the EW is measured by cursor placements an abbreviated table (see Figure 6) is displayed. The columns are self-evident except for EW 0 and EW 1.

EW 0 is the normalized area between the continuum, observations and the cursor placements.

EW 1 is the normalized area of the line computed from the fit parameters including the continuum height.

Note that if one were fitting rotationally broadened profiles the FWHM heading would be replaced by VSINI.

5B. VLINE.DAT (FORTRAN UNIT 3)

Originally the results were directly logged to the line printer but we have found this to be wasteful of paper since people hardly ever pick the paper up. This output now goes to VLINE.DAT and can be obtained at the end of a run by the command:

$PRINT VLINE.DAT

As VLINE is rerun new versions of VLINE.DAT are created. You will have to keep track of them.

We include here one of the tables resulting from a VLINE run (Figure 7). The columns in order are largely self-explanatory however columns 7-11 need further clarifiaction.

Column 7 EW(OBS) is the normalized area between continuum, data and two cursor placements.

Column 8 EW(FUNCT) is the normalized area between continuum, composite funcion and two cursor placements.

Column 9 EW(ONE) is the normalized area of the line in question computed from the fit parameters.

Column 10 DEPTH(OBS) is the normalized depth with respect to the continuum and the data point nearest to line centre.

Column 11 DEPTH(ONE) is the normalized depth of the line in question computed from the fit parameters.

In both 5B and 5C following, the blanks in the tables have these meanings.

i) If RV(MEAS) is blank then either a line identification failed or the measures were made in the RECORD mode.

ii) If EW(OBS), EW(FUNCT) and DEPTH(OBS) are blank the EW was not made by cursor placements (L command was used at STEP 4.4).

iii) Where only an RV is given the measures were made by encoding the cursor (M command was used at STEP 4.3).

5C. OUTPUT FILE

The structure of this file (Figure 8) is identical to the LINE PRINTER output. The output file can be read by the following format

```
HEADER 1   (87A1)
HEADER 2   (//, 73A1, //, 127A1)
HEADER 3   (98A1, /)
DATA       (1X, I3, 1X, A4, 1X, F9.3, F7.3, F9.2, F7.1, 3F7.2, 3F6.2,
            F7.0, 1X, A4, F5.2, 1X, 15A2)
```

5D. TEKTRONIX HARDCOPY

The Tektronix screen can be copied using the hardcopy unit - make a copy using the copy switch on the right-hand side. Make sure that the copy unit is properly exercised. Xeroxes of these hardcopies can be seen in the appendices in Section 6 where a partial measuring run has been duplicated from the TEKTRONIX screen.

Figure 6. Sample TEKTRONIX Display

DE BQE;FIT GLR45COMKDHUSOBNTFEW@OK?LNBPWOS^;WEW TJKRNBOS
Gaus N 38

*	Lam	err	RV	EW 0	EW 1	D fit	FWHM	Comment
	4552.524	0.030		464.0	495.8	0.25	1.83	Com? OK
	4567.721	0.033		341.0	359.7	0.19	1.75	Com? OK
	4574.694	0.056		238.2	260.1	0.13	1.83	Com? OK

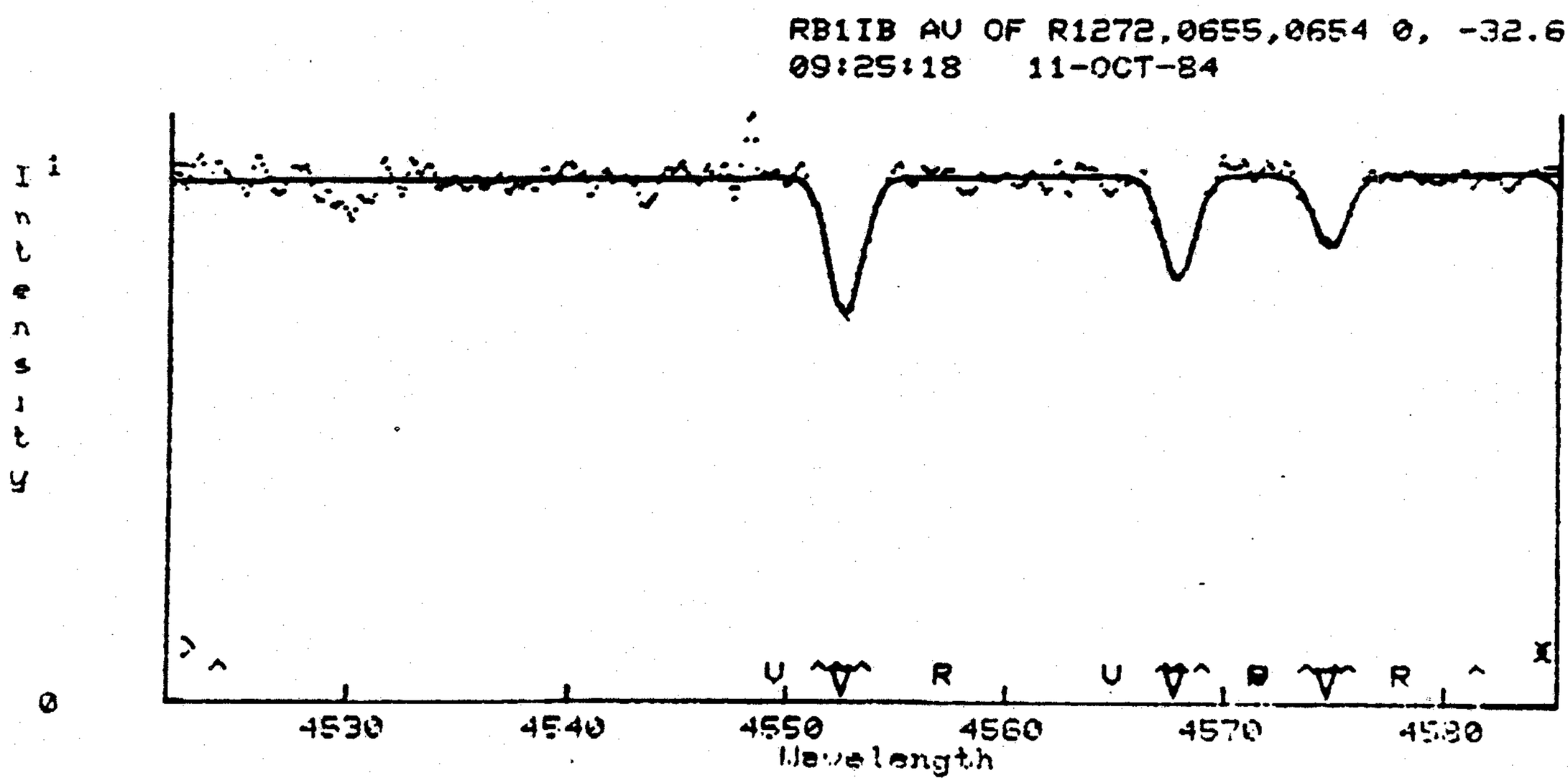


Figure 7. Line Printer Output

Stellar Wavelengths

1	3659.423	2	3660.280	3	3661.221	4	3662.258	5	3663.405	6	3664.679	7	3666.097	8	3667.684	9	3669.466	10	3671.478
11	3673.761	12	3676.365	13	3679.355	14	3682.810	15	3686.834	16	3691.557	17	3697.154	18	3703.855	19	3711.973	20	3721.941
21	3734.370	22	3750.154	23	3770.632	24	3797.900	25	3819.606	26	3835.386	27	3853.657	28	3856.021	29	3862.592	30	3867.480
31	3888.648	32	3889.051	33	3918.977	34	3920.677	35	3926.530	36	3933.664	37	3954.370	38	3964.727	39	3968.465	40	3970.075
41	3994.996	42	4009.270	43	4026.140	44	4026.189	45	4069.794	46	4072.162	47	4075.868	48	4088.862	49	4097.330	50	4101.738
51	4103.394	52	4116.103	53	4119.221	54	4120.812	55	4128.051	56	4130.876	57	4143.759	58	4153.304	59	4168.970	60	4187.050
61	4189.788	62	4199.830	63	4267.160	64	4276.050	65	4317.144	66	4319.635	67	4325.770	68	4340.466	69	4349.428	70	4351.270
71	4366.896	72	4379.100	73	4387.928	74	4414.904	75	4416.975	76	4437.549	77	4471.477	78	4471.507	79	4481.228	80	4510.906
81	4514.861	82	4523.590	83	4541.610	84	4549.550	85	4552.622	86	4567.841	87	4574.758	88	4583.701	89	4590.974	90	4596.178
91	4634.145	92	4638.857	93	4640.632	94	4641.811	95	4641.875	96	4649.141	97	4650.844	98	4661.635	99	4676.234	100	4651.460
101	4685.740	102	4713.143	103	4861.327	104	4921.929												

Stellar Identification

1	H 33	2	H 32	3	H 31	4	H 30	5	H 29	6	H 28	7	H 27	8	H 26	9	H 25	10	H 24
11	H 23	12	H 22	13	H 21	14	H 20	15	H 19	16	H 18	17	H 17	18	H 16	19	H 15	20	H 14
21	H 11	22	H 10	23	H 9	24	H 8	25	He I	26	H 7	27	Si 2	28	Si 2	29	Si 2	30	He 1
31	He 1	32	H 6	33	C 2	34	C 2	35	He I	36	Ca 2	37	N 2	38	He 2	39	Ca 2	40	H 5
41	N 2	42	He 1	43	He 1	44	He 1	45	O 2	46	O 2	47	O 2	48	Si 4	49	N 3	50	HDel
51	N 2	52	Si 4	53	O 2	54	He 1	55	Si 2	56	Si 2	57	He 1	58	O 2	59	He 1	60	C 3
61	O 2	62	He 2	63	C 2	64	O 2	65	O 2	66	O 2	67	O 2	68	HGam	69	O 2	70	O 3
71	O 2	72	N 3	73	He 1	74	O 2	75	O 2	76	He 1	77	He 1	78	HHe 1	79	Mg 2	80	N 3
81	N 3	82	N 3	83	He 2	84	Fe 2	85	Si 2	86	Si 2	87	Si 2	88	Fe 2	89	O 2	90	O 3
91	N 3	92	O 2	93	N 3	94	O b2	95	N b3	96	O 2	97	O 2	98	O 2	99	O 2	100	C 3
101	He 2	102	He 1	103	HBet	104	He 1												

Plotting Widths

1	50.000	2	50.000	3	50.000	4	50.000	5	50.000	6	50.000	7	50.000	8	50.000	9	50.000	10	50.000
11	50.000	12	50.000	13	50.000	14	50.000	15	50.000	16	50.000	17	50.000	18	50.000	19	50.000	20	50.000
21	50.000	22	50.000	23	50.000	24	50.000	25	50.000	26	50.000	27	50.000	28	50.000	29	50.000	30	50.000
31	50.000	32	50.000	33	50.000	34	50.000	35	50.000	36	50.000	37	50.000	38	50.000	39	50.000	40	50.000
41	50.000	42	50.000	43	50.000	44	50.000	45	50.000	46	50.000	47	50.000	48	50.000	49	50.000	50	50.000
51	50.000	52	50.000	53	50.000	54	50.000	55	50.000	56	50.000	57	50.000	58	50.000	59	50.000	60	50.000
61	50.000	62	50.000	63	50.000	64	50.000	65	50.000	66	50.000	67	50.000	68	50.000	69	50.000	70	50.000
71	50.000	72	50.000	73	50.000	74	50.000	75	50.000	76	50.000	77	50.000	78	50.000	79	50.000	80	50.000
81	50.000	82	50.000	83	50.000	84	50.000	85	50.000	86	50.000	87	50.000	88	50.000	89	50.000	90	50.000
91	50.000	92	50.000	93	50.000	94	50.000	95	50.000	96	50.000	97	50.000	98	50.000	99	50.000	100	50.000
101	50.000	102	50.000	103	50.000	104	50.000												

R81IB AV OF R1272,0655,0654 0, -32.6 reduced at 10:28:48 on 11-OCT-84
Stellar line file name is BSTAR.STR
Output file name is DUM.DAT

Stellar Measures

#	Ion	Lam Meas	Lam err	RV Meas	RV err	EW(mA) Obs	EW(mA) Funct	EW(mA) One	Depth Obs	Depth One	Width FWHM	Width vsini	Profile type	Profile Beta	Comment
1	N 2	3954.667	0.099	22.49	7.5			186.2		0.08	2.14	162	Gaus	0.60	
		3964.713	0.047		3.5			355.2		0.17	1.95	147	Gaus	0.60	
		3969.824	0.036		2.7			1498.2		0.38	3.69	279	Gaus	0.60	
		3973.268	0.051		3.8			274.0		0.16	1.57	118	Gaus	0.60	
1	N 2	3954.667	0.099	22.48	7.5	150.8	170.7	171.1	0.07	0.08	2.05	155	Gaus	0.60	
		3964.720	0.047		3.6	2173.6	2113.9	350.8	0.20	0.17	1.94	147	Gaus	0.60	
		3969.829	0.035		2.7	2200.9	2118.3	1492.9	0.40	0.38	3.68	278	Gaus	0.60	
		3973.273	0.051		3.9	2196.0	2121.2	274.7	0.19	0.16	1.57	118	Gaus	0.60	
5	N 2	3994.947	0.034	-3.67	2.5	239.6	239.1	239.4	0.16	0.18	1.26	95.	Gaus	0.60	
6	He 1	4009.143	0.052	-9.47	3.9	334.8	333.0	333.2	0.15	0.15	2.07	155	Gaus	0.60	
8	He 1	4026.062	0.025	-9.42	1.9	732.1	705.4	705.7	0.33	0.31	2.12	158	Gaus	0.60	
9	O 2	4069.735	0.064	-4.34	4.7	426.0	432.7	229.3	0.15	0.15	1.43	105	Gaus	0.60	OK
10	O 2	4072.151	0.069	-0.82	5.1	423.2	429.2	204.5	0.12	0.14	1.39	102	Gaus	0.60	
11	O 2	4075.800	0.050	-5.00	3.7	223.8	224.6	223.7	0.18	0.17	1.21	89	Gaus	0.60	
12	Si 4	4088.891	0.069	2.10	5.0	122.4	157.0	157.3	0.11	0.12	1.23	90	Gaus	0.60	
14	HDel	4101.713	0.042	-1.80	3.1	1803.1	1544.6	1545.7	0.41	0.38	3.81	279	Gaus	0.60	
16	Si 4	4116.090	0.071	-0.96	5.2	113.9	108.8	110.7	0.10	0.09	1.12	82	Gaus	0.60	
17	O 2	4119.075	0.123	-10.65	9.0	481.6	474.8	136.0	0.12	0.11	1.20	87	Gaus	0.60	
18	He 1	4120.701	0.082	-8.06	6.0	481.9	474.8	338.5	0.19	0.19	1.65	120	Gaus	0.60	
		4143.843	0.112		8.1	481.5	444.1	442.4	0.21	0.19	2.22	161	Gaus	0.60	
27	C 2	4267.064	0.063	-6.78	4.4	228.4	241.9	242.1	0.14	0.14	1.60	112	Gaus	0.60	
		4253.746	0.084		5.9	201.6	213.3	213.6	0.11	0.11	1.75	123	Gaus	0.60	OK
29	O 2	4317.111	0.127	-2.30	8.8	245.1	307.9	162.6	0.10	0.10	1.52	106	Gaus	0.60	
30	O 2	4319.459	0.129	-12.25	9.0	237.1	307.9	145.3	0.08	0.10	1.42	99	Gaus	0.60	
32	HGam	4340.287	0.051	-12.32	3.5	2021.6	1809.9	1814.5	0.44	0.41	4.17	288	Gaus	0.60	
33	O 2	4349.211	0.219	-14.93	15.1	781.1	591.8	589.4	0.18	0.16	3.39	234	Gaus	0.60	OK
35	O 2	4366.755	0.050	-9.69	3.4	179.4	194.6	194.7	0.13	0.13	1.40	96	Gaus	0.60	
37	He 1	4387.970	0.035	2.88	2.4	571.3	556.5	556.5	0.23	0.24	2.19	149	Gaus	0.60	
		4467.254	0.294		19.7	1090.4	1109.9	235.7	0.05	0.05	4.06	272	Gaus	0.60	
		4471.438	0.034		2.3	1089.8	1106.8	871.6	0.36	0.34	2.38	159	Gaus	0.60	
		4480.856	0.057		3.8	193.8	241.7	241.2	0.14	0.13	1.77	118	Gaus	0.60	OK
49	Si 2	4552.522	0.027	-6.59	1.8	486.9	509.4	509.4	0.27	0.26	1.86	123	Gaus	0.60	
50	Si 2	4567.718	0.035	-8.05	2.3	349.5	359.9	359.9	0.19	0.19	1.74	114	Gaus	0.60	
51	Si 2	4574.691	0.052	-4.43	3.4	227.8	254.2	254.1	0.12	0.13	1.79	118	Gaus	0.60	OK
53	O 2	4590.980	0.129	0.36	8.4	221.2	223.0	223.2	0.14	0.12	1.71	112	Gaus	0.60	
54	O 2	4596.170	0.133	-0.53	8.7	131.9	153.8	153.8	0.10	0.11	1.33	87	Gaus	0.60	OK

Figure 8. Output File DUM.DAT*

RB11B AV OF R1272.0655.0654 0. -32.6 reduced at 10:28:48 on 11-OCT-84

---------- Stellar Measures ----------

#	Ion		------Lam------ Meas	err	------RV----- Meas	err	------EW(mA)------ Obs	Funct	One	---Depth-- Obs	One	---Width---Profile- FWHM	vsini	type	Beta	
1	N	2	3954.667	0.099	22.49	7.5			186.2		0.08	2.14	162	Gaus	0.60	
			3964.713	0.047		3.5			355.2		0.17	1.95	147	Gaus	0.60	
			3969.824	0.036		2.7			1498.2		0.38	3.69	279	Gaus	0.60	
			3973.268	0.051		3.8			274.0		0.16	1.57	118	Gaus	0.60	
1	N	2	3954.667	0.099	22.48	7.5	150.8	170.7	171.1	0.07	0.08	2.05	155	Gaus	0.60	
			3964.720	0.047		3.6	2173.6	2113.9	350.8	0.20	0.17	1.94	147	Gaus	0.60	
			3969.829	0.035		2.7	2200.9	2118.3	1492.9	0.40	0.38	3.68	278	Gaus	0.60	
			3973.273	0.051		3.9	2196.0	2121.2	274.7	0.19	0.16	1.57	118	Gaus	0.60	
5	N	2	3994.947	0.034	-3.67	2.5	239.6	239.1	239.4	0.16	0.18	1.26	95	Gaus	0.60	
6	He	1	4009.143	0.052	-9.47	3.9	334.8	333.0	333.2	0.15	0.15	2.07	155	Gaus	0.60	
8	He	1	4026.062	0.025	-9.42	1.9	732.1	705.4	705.7	0.33	0.31	2.12	158	Gaus	0.60	
9	O	2	4069.735	0.064	-4.34	4.7	426.0	432.7	229.3	0.15	0.15	1.43	105	Gaus	0.60	OK
10	O	2	4072.151	0.069	-0.82	5.1	423.2	429.2	204.5	0.12	0.14	1.39	102	Gaus	0.60	
11	O	2	4075.800	0.050	-5.00	3.7	223.8	224.6	223.7	0.18	0.17	1.21	89	Gaus	0.60	
12	Si	4	4088.891	0.069	2.10	5.0	122.4	157.0	157.3	0.11	0.12	1.23	90	Gaus	0.60	
14	HDel		4101.713	0.042	-1.80	3.1	1803.1	1544.6	1545.7	0.41	0.38	3.81	279	Gaus	0.60	
16	Si	4	4116.090	0.071	-0.96	5.2	113.9	108.8	110.7	0.10	0.09	1.12	82	Gaus	0.60	
17	O	2	4119.075	0.123	-10.65	9.0	481.6	474.8	136.0	0.12	0.11	1.20	87	Gaus	0.60	
18	He	1	4120.701	0.082	-8.06	6.0	481.9	474.8	338.5	0.19	0.19	1.65	120	Gaus	0.60	
			4143.843	0.112		8.1	481.5	444.1	442.4	0.21	0.19	2.22	161	Gaus	0.60	
27	C	2	4267.064	0.063	-6.78	4.4	228.4	241.9	242.1	0.14	0.14	1.60	112	Gaus	0.60	
			4253.746	0.084		5.9	201.6	213.3	213.6	0.11	0.11	1.75	123	Gaus	0.60	OK
29	O	2	4317.111	0.127	-2.30	8.8	245.1	307.9	162.6	0.10	0.10	1.52	106	Gaus	0.60	
30	O	2	4319.459	0.129	-12.25	9.0	237.1	307.9	145.3	0.08	0.10	1.42	99	Gaus	0.60	
32	HGam		4340.287	0.051	-12.32	3.5	2021.6	1809.9	1814.5	0.44	0.41	4.17	288	Gaus	0.60	
33	O	2	4349.211	0.219	-14.93	15.1	781.1	591.8	589.4	0.18	0.16	3.39	234	Gaus	0.60	OK
35	O	2	4366.755	0.050	-9.69	3.4	179.4	194.6	194.7	0.13	0.13	1.40	96	Gaus	0.60	
37	He	1	4387.970	0.035	2.88	2.4	571.3	556.5	556.5	0.23	0.24	2.19	149	Gaus	0.60	
			4467.254	0.294		19.7	1090.4	1109.9	235.7	0.05	0.05	4.06	272	Gaus	0.60	
			4471.438	0.034		2.3	1089.8	1106.8	871.6	0.36	0.34	2.38	159	Gaus	0.60	
			4480.856	0.057		3.8	193.8	241.7	241.2	0.14	0.13	1.77	118	Gaus	0.60	OK
49	Si	2	4552.522	0.027	-6.59	1.8	486.9	509.4	509.4	0.27	0.26	1.86	123	Gaus	0.60	
50	Si	2	4567.718	0.035	-8.05	2.3	349.5	359.9	359.9	0.19	0.19	1.74	114	Gaus	0.60	
51	Si	2	4574.691	0.052	-4.43	3.4	227.8	254.2	254.1	0.12	0.13	1.79	118	Gaus	0.60	OK
53	O	2	4590.980	0.129	0.36	8.4	221.2	223.0	223.2	0.14	0.12	1.71	112	Gaus	0.60	
54	O	2	4596.170	0.133	-0.53	8.7	131.9	153.8	153.8	0.10	0.11	1.33	87	Gaus	0.60	OK

APPENDIX 1

FORM A STANDARD PROFILE FROM STELLAR DATA

Not all shapes can be fitted by Gaussian, Lorentzian or rotational functions. In this appendix we describe the creation of such a standard profile. These profiles, which may be rendered symmetric (by folding), are defined in units of the FWHM and therefore look very much the same to VLINE as the analytic functions identified above.

The program steps are as follows:

1. Measure background level, line positions, strength and FWHM.
2. Manipulate image if more data are needed.
3. Check the derived parameters.
4. Normalize the final profile and store it.

STEP 1

The same image seen in VLINE is displayed and one may select a part of this to generate a std profile. Measurements of the line centre must be done now. This measurement is made by fitting a parabola to the peak by making 2 cursor settings on each side of the peak.

PROMPT: Measure <x>, <d>, <c>; TBJELRDCPF

REPLY: Make two cursor placements with the thumbwheel and the spacebar.
Enter T to measure the mean position with the cursor. These measures if made first will leave you at STEP 2.
The following commands will (ultimately) result in the data being replotted, but not until an F has been struck.
Define new window by a left (L) and right (R) cursor placement.
C encodes the Y cursor to define a new background level.
D encodes the Y cursor for a new maximum height.
End these changes with an F. The screen will clear and the data will be replotted leaving you again at STEP 1.
The following commands cause the program to branch.
B return to the beginning of this subroutine, and negate any current measures.
J skips to next step.
P skips to STEP 3 where the std profile is finally formed.
E returns the user to VLINE main.

STEP 2

This is a branching step. Once can begin anew, branch to STEP 1 or move on to define the standard profile.

PROMPT: OPTIONS: BP M=measure anew, E=end

REPLY: B to re-initialize all the measures and return to STEP 1.
M returns to STEP 1 for another series of measures.
P continue to next step
E abort process and return to VLINE main.

STEP 3.

Here you have a final chance to alter the values of the background height, line position and depth prior to the final derivation of the FWHM and the creation of a normalized profile p(x(units of FWHM), intensity). After these questions are answered the displayed profile may be folded, inverted and stored.
The questions invite the user to either adopt the current parameter or alter the value by making a setting with the X and Y cursors and encoding the position by striking the T key. At the end of these questions the following prompt appears.

PROMPT: Fold profile; invert, store I; adopt, store A; E=end

REPLY: If you are happy with the profile as is enter A.
Fold the profile with an F. The resultant profile will be plotted in squares. Store it with an A command. Invert the profile (to an absorption line) and store it with an I.
Skip to main program with an E.
If you elected to store the profile you will be prompted for a file name. I suggest that you append .ccf to this name so that you know later what operation this file resulted from.

STEP 4.

Here one can return to the beginning of the step or to the main program.

PROMPT: What next? B=restart, E=end.

REPLY: B to reset all the current measures to zero and begin anew at STEP 1.
E returns to VLINE main.

6. A VLINE RUN

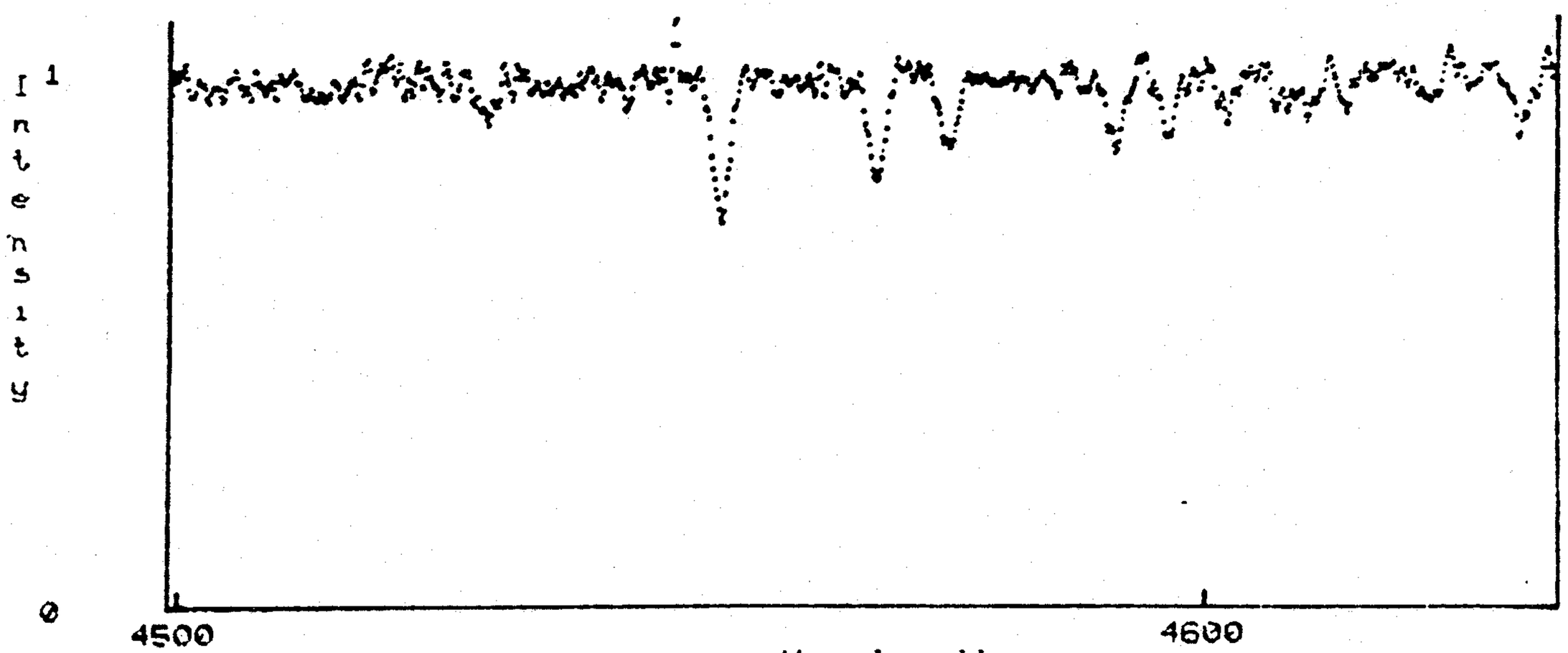
On the following pages a partial run is illustrated by means of RUN-TIME TEKTRONIX copies. Because these illustrations were made at different times there will be small differences in the derived values and the display but they will be quite adequate for demonstration purposes.
It is also possible that messages will differ slightly from those you will encounter but this is to be expected in an evolving program such as VLINE.

Appendix 2. RECORD mode (STEP 4.1, 4.2)

Lam: lo 4498.950 hi 4633.950 # pts 901 13:55:33 10-0

DE BQE;

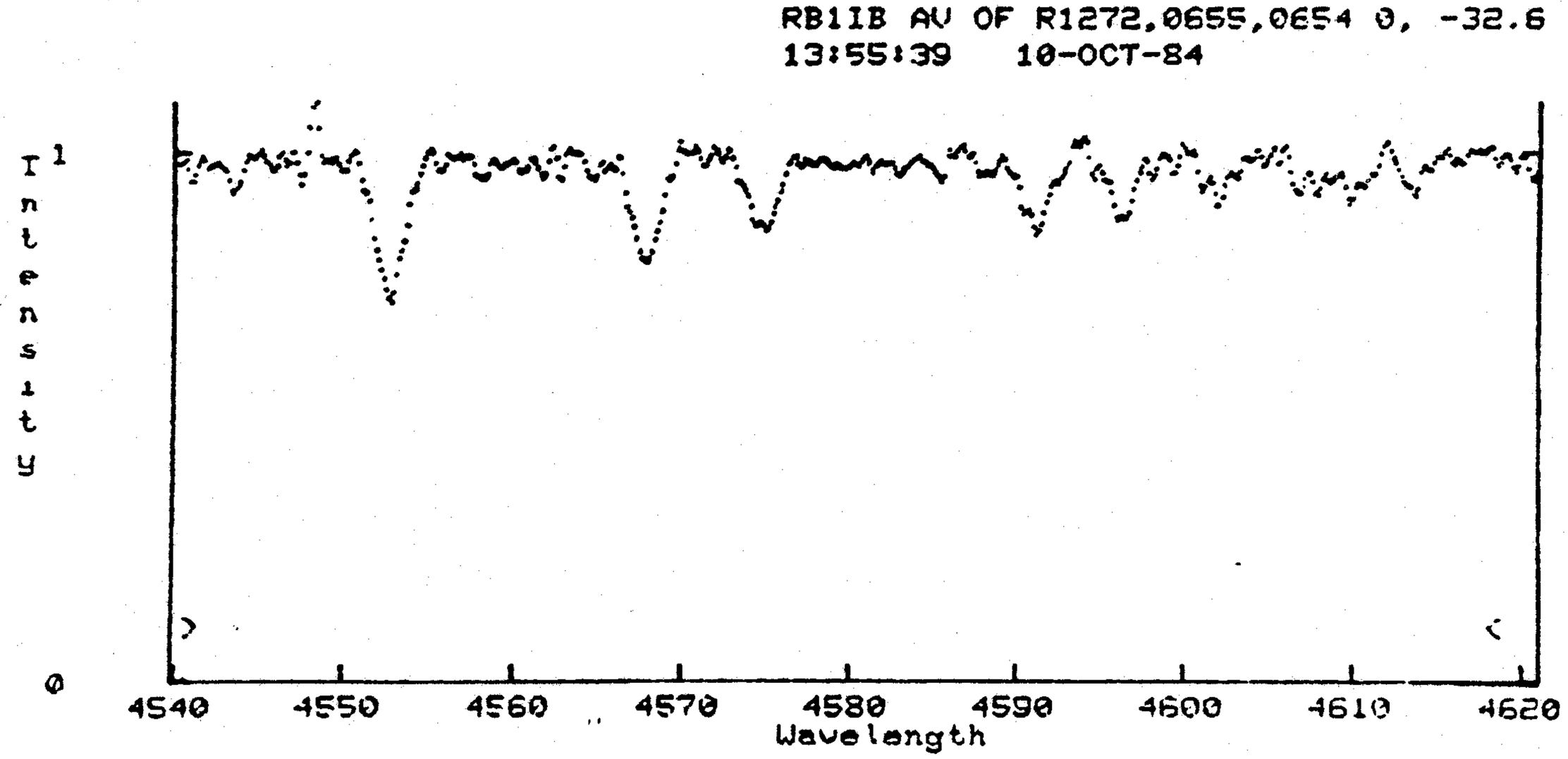
EX?~QNESOB<X>@P



Appendix 3. RECORD mode (Step 4.3)

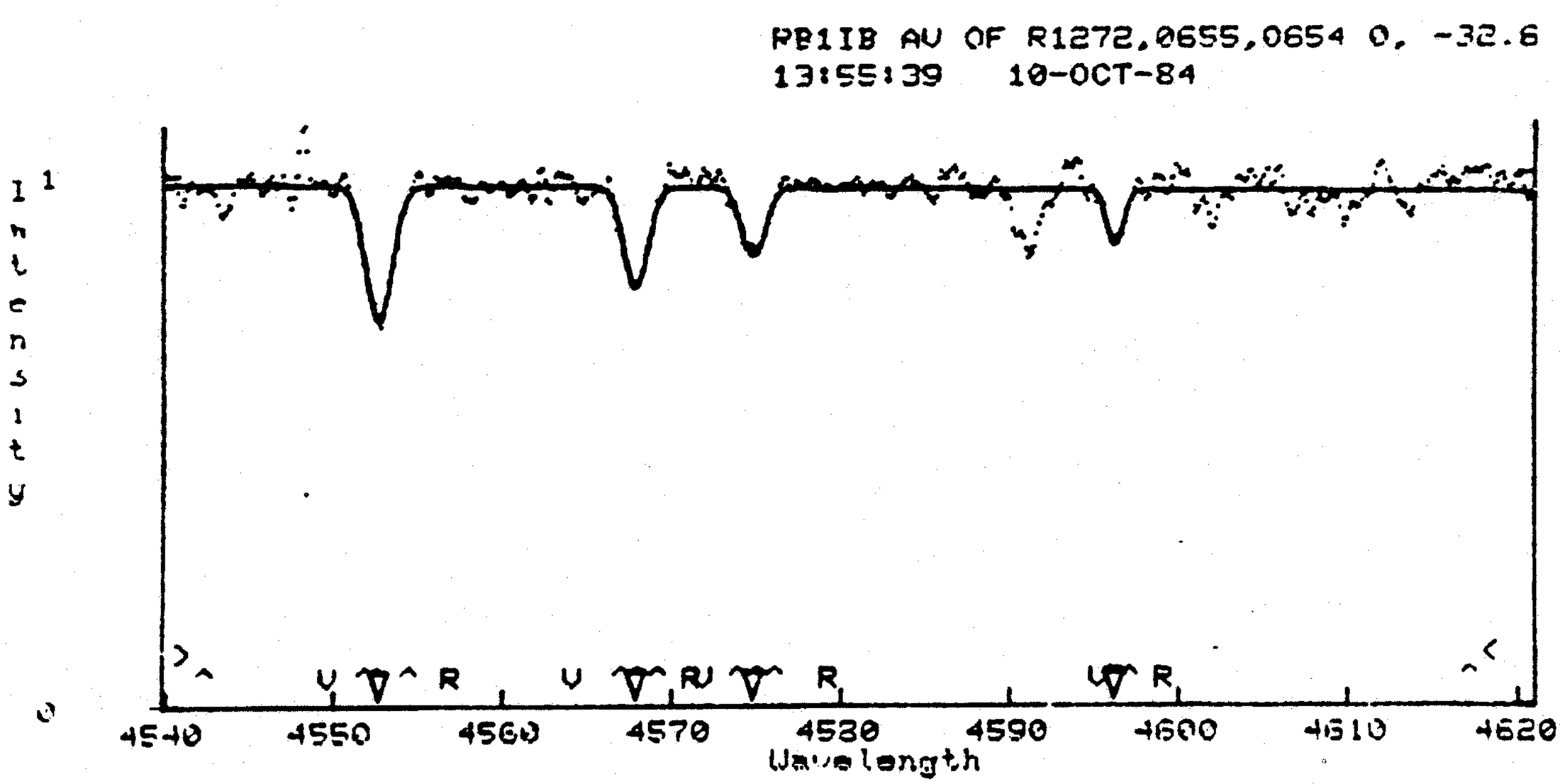
DE BQE;FIT GLR4SOQMKDHUSOBMTFEW@

Gaus N 38



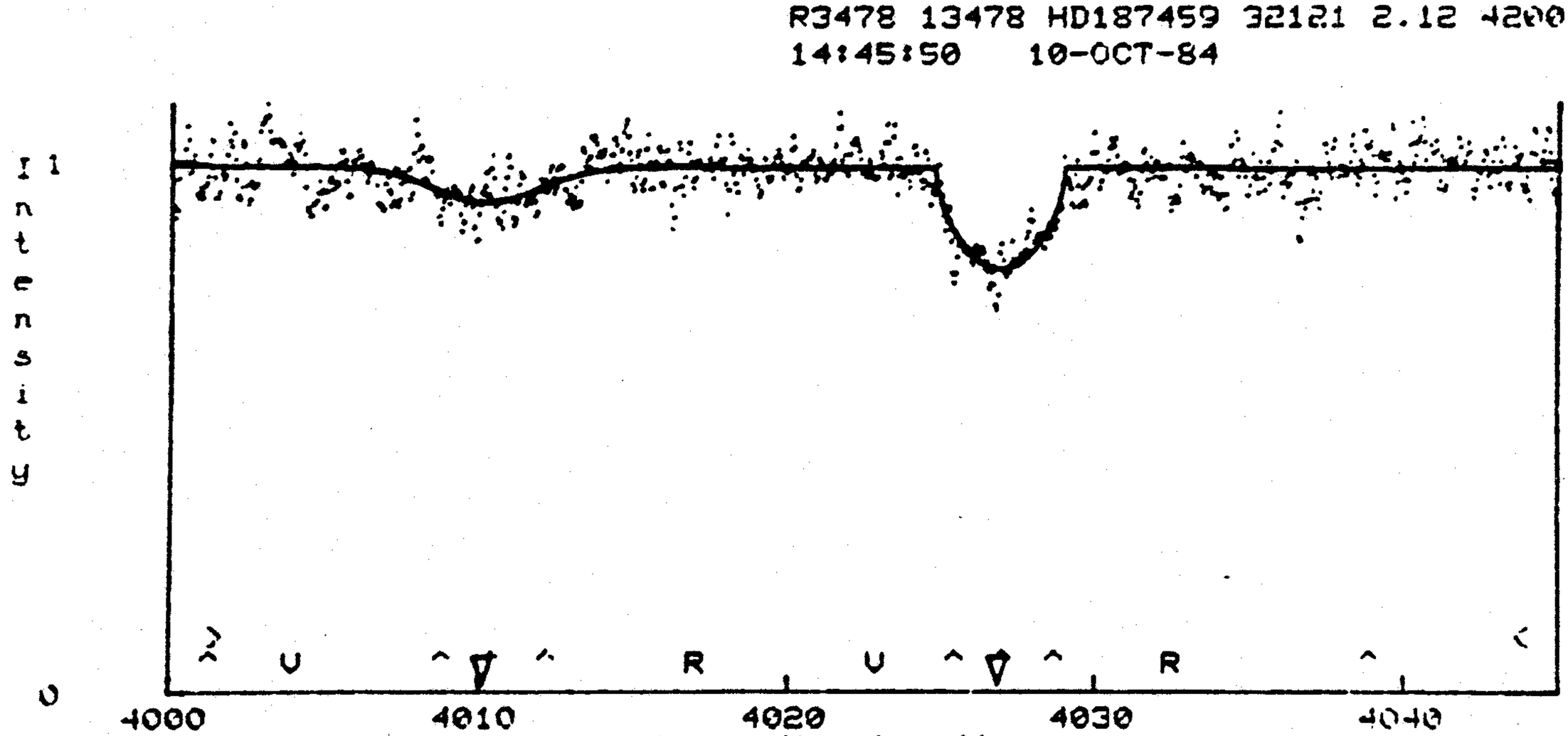
Appendix 4. RECORD mode (Step 4.5)

```
DE BQE;FIT GLR45COMK.DHUSOBNTFEW@K.TLNBPWOS^; WEW TJKRNBOS
                                                Gaus N 38

#    Lam      err      RV    EW 0   EW 1  D fit   FWHM          Comment
   4552.529 0.039          489.7  506.3   0.26   1.85 Com? OK
   4567.717 0.051          320.3  342.4   0.19   1.69 Com? OK
   4574.688 0.078          175.7  228.4   0.13   1.67 Com? OK
   4596.176 0.078          128.3  132.4   0.10   1.20 Com? OK
```



Appendix 5. RECORD mode (Step 4.5) - note the rotational velocity

```
Lam: lo 4000.000 hi 4045.000 * pts  901 P3478 10-OCT-84
                                                          Rota N  8
                DE BGE;FIT GLR4SCOMKDHUSOBNITFEW@K.?LNBPWOS-.; WEW TJKRNBOS
EX?^QNE5OB<X>9P                                           Gaus N 38

  *    Lam      err      RU    EW 0   EW 1  D fit   FWHM          Comment
     4010.143 0.178          320.7  291.3   0.07   4.06 Com? OK
     4026.841 0.032          636.6  599.0    0.2    157 Com? OK
```



Appendix 6. What now? (Step 4.6)

```
What now?
S    return to main program and Status Table
B    return to the current full screen plot
N    return to delimit the current screen plot
O    to plot the next line or record
W    Go to specific starting wavelength
```

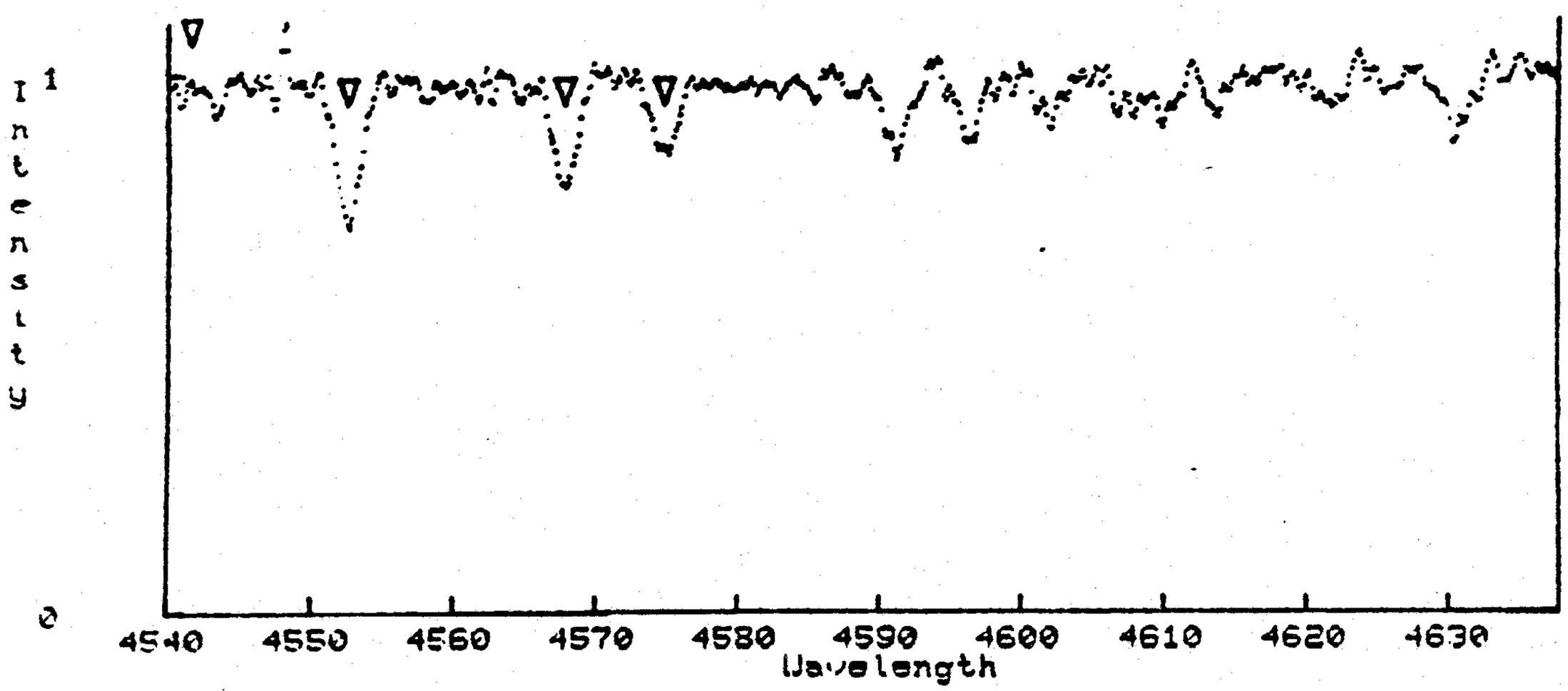
Appendix 7. RECORD mode. (Step 5). Current Status Table

```
                    ------Current Status------  Mode: record
Header: RB1IB AV OF R1272,0655,0654 0, -32.6
Wavelength: low  4499.000 (WL)
            High  4634.000
            Range   135.000 (WD)
Profile: default profile type; 1=G,2=L,3=R  G (IP)
         Limb darkening    0.60 (BE)
Data: Current record       (CR)
      Next record       (NR)
      Smoothing  0=1 pt,1=3 pt,2=9 pt,...  0 (SM)
      Max data value       1.091
      Current max       1.091
      Order of area smoothing poly  2 (NT)
Record keystrokes (Memorize or ROBOT mode) No  (RE)
Playback keystrokes (ROBOT mode) No  (PL)
Display: # pts plotted    901 (NP)
         Fraction of these the screen can be shifted (1/entry)    5 (NF)
         Screen height (max=700)    400. (HT)
Disk: Read in new data (NS)
      Exit from VLINE (EX)
I/O files: Stellar line list          No  (ST)
           Output file                No  (OU)
Options: WL,WD,IP,BE,SM,NT,NP,NF,HT:Exit=EX,End entries=EN
Enter two letters--end with EN,CR,NR,NS,EX,ST,OU
```

Appendix 8. LINE mode (Step 4.1) Note previously measured lines.

Line 47 Lam 4541.610 # pts 652 RB1IB 10-OCT-84

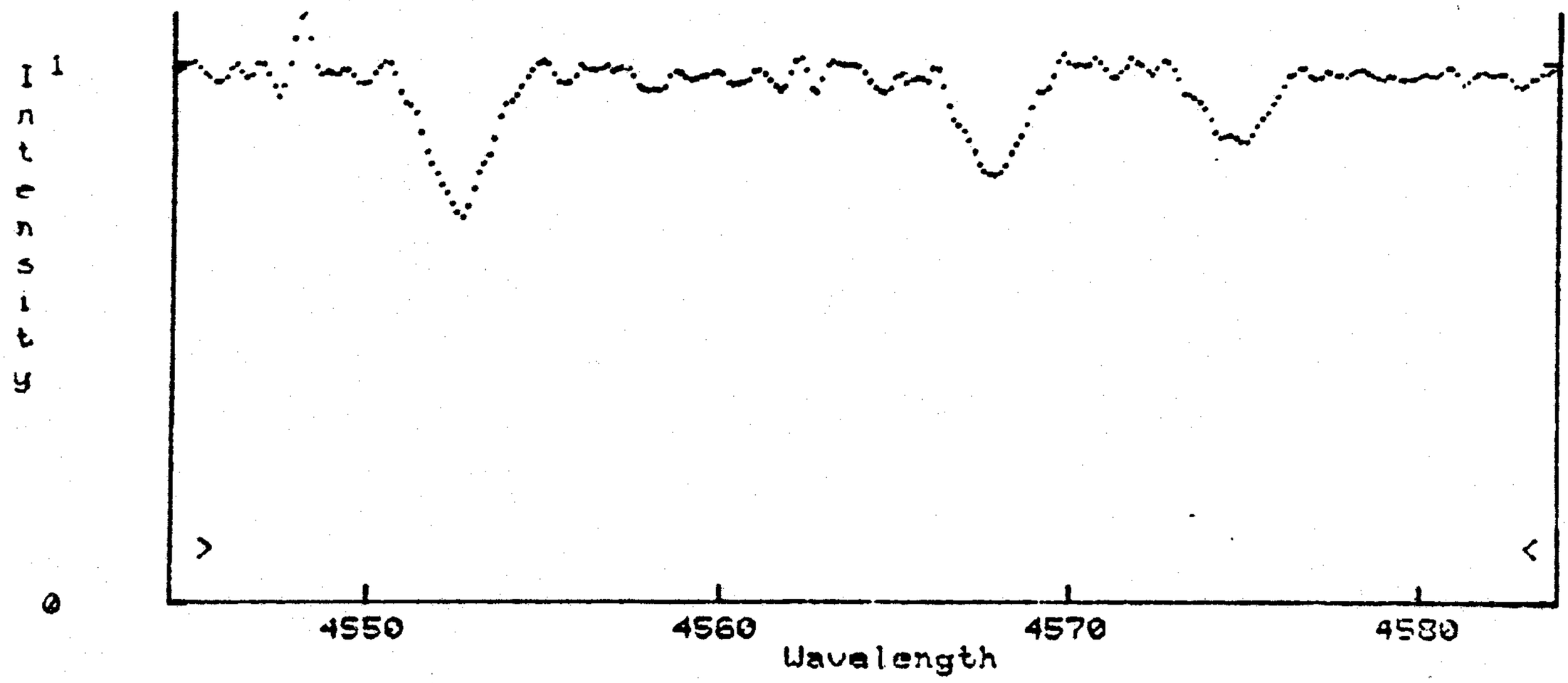
EX?^QNE SOB<X>@P



Appendix 9. LINE mode (Step 4.3)

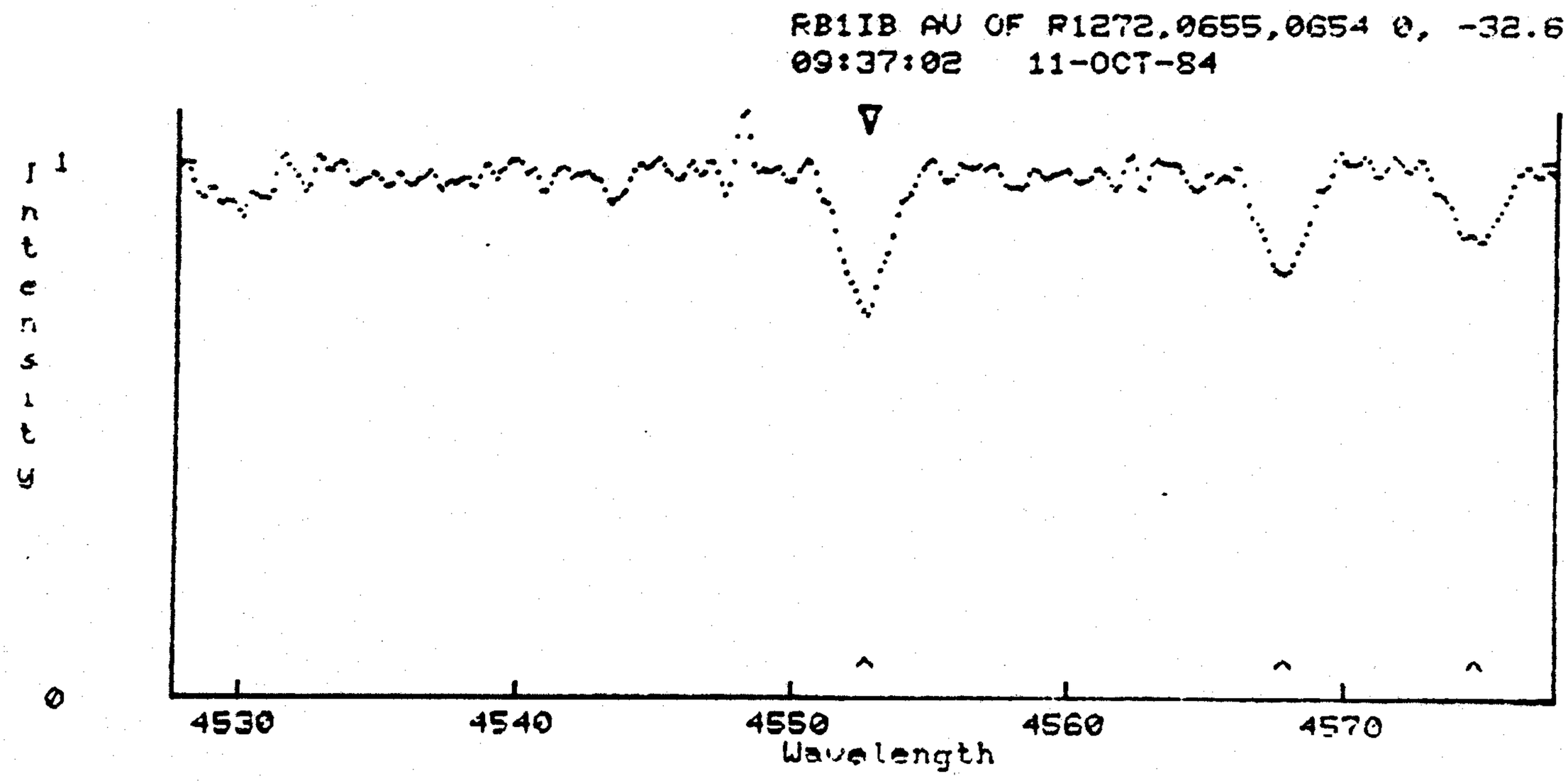
DE BQE;FIT GLP45CQMKDHUSOBNTFEW@

Gaus N 38



Appendix 10. LINE mode (Step 4.3)

```
Line  49 Lam  4552.622 # pts  334 RB1IB 11-OCT-84
                    FIT GLR45CQMKDHUEOBHTFEW9
EX?^QNESOB<X>WF                                          Gaus N 38
 49          4552.575              -3.10
 50          4567.726              -7.52
 51          4574.608              -9.80
```



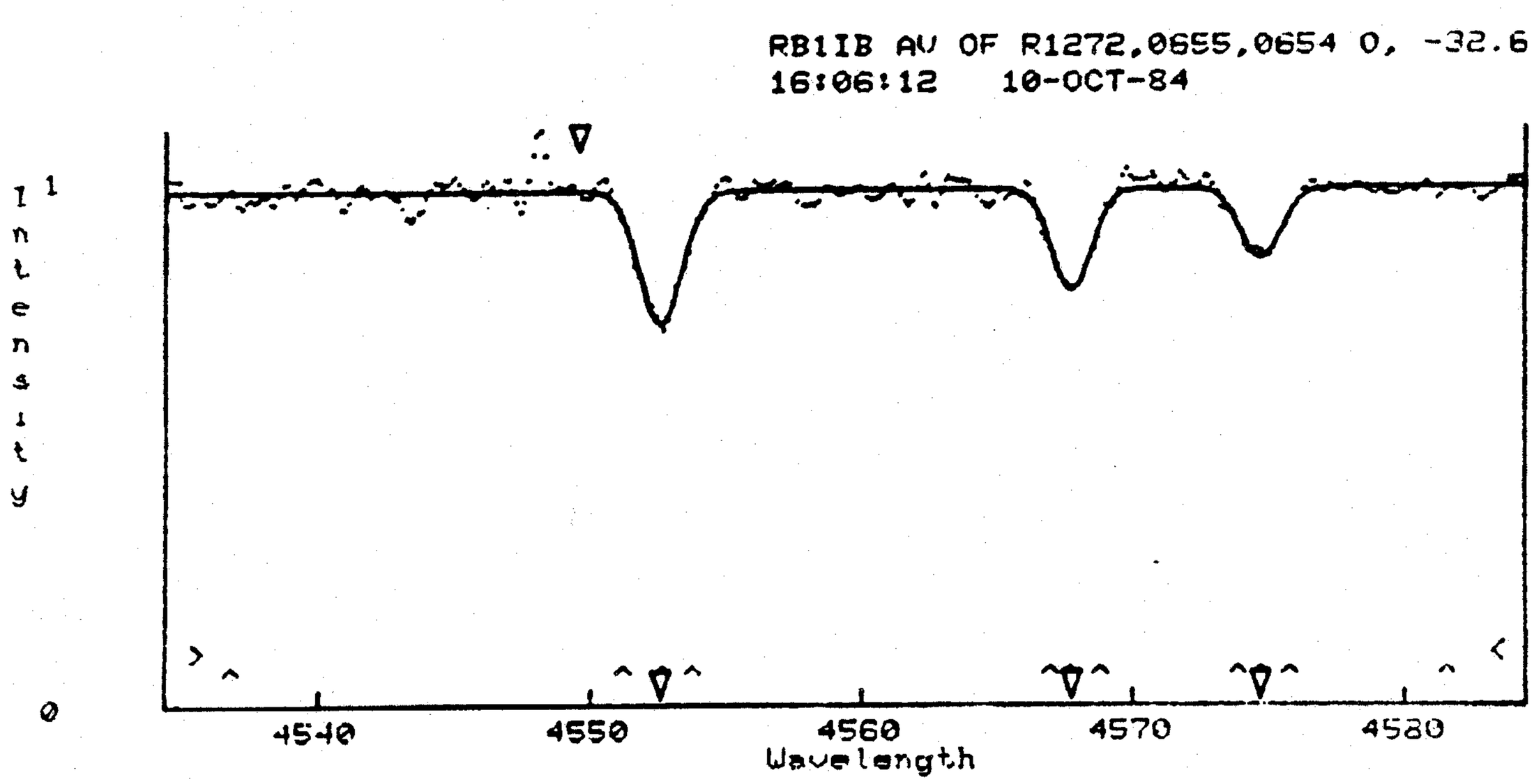
Appendix 11. LINE mode (Step 4.4)

Line 48 lam 4549.550 * pts 334 RB1IB 10-OCT-84

DE EQE;FIT GLR45CQMKDHUSOBNTFEW@OK?LNBPWOS^;

EX?^QNB5OB<X>@F

Gaus N J8



Appendix 12. LINE mode (Step 4.5) Display of final results.

```
Line  48 Lam  4549.550 # pts  334 RB1IB 10-OCT-84

                  DE BUE;FIT GLR4SCGMKDHUSOBNTFEW@UK?LIIBPWOS^;WEW TJKRNBOS
EX?^QNE5OB<X>@P                                                  Gaus N 38

  #    Lam       err      RV    EW 0   EW 1  D fit   FWHM          Comment
 49 4552.523 0.027          489.2 501.3   0.26   1.84 Com? OK
    4567.719 0.034          345.0 359.3   0.19   1.74 Com? OK
    4574.692 0.051          236.5 256.3   0.13   1.80 Com? OK
```