Table 1. PDS Data File Naming Convention

Data Type	Prefix		Example for Plate 12345 Tape	Disk
Raw Spectroscopic Data:				
Calibration	T	Scan 1 (λ_1) Scan 2 (λ_2) Scan 3 (λ_3)	T2345	T2345.FTS
Clear	L		L2345	L2345.FTS
Arc	F	Side 1 Side 2	F2345	F2345.FTS
Stellar	S		S2345	S2345.FTS
Processed Stellar Data:				
Filtered	V			V2345.FTS
Linearized (λ)	W			W2345.FTS
Linearized (ln λ)	U			U2345.FTS
Intensity	I			I2345.FTS
Rectified	R			R2345.FTS
Raw Grens Data:				
Calibration	T		T2345	T2345.FTS
FWHM	L		L2345	L2345.FTS
Stellar/Galaxy	S		S2345	G2345.FTS
Processed Grens Data:				
Intensity				J2345.FTS

TSTACK

The program TSTACK will read a FITS file, perform a velocity shift and convert it to a specified λ interval and increment for plotting and/or store it in λ or ln λ form (suitable for use with VCROSS). Files harmonized in this way may be stack-plotted and have simple arithmetic performed on them, for example, one may want to stack-plot a series of differences between spectra. The options availabe to the user are:

(i) Convert a FITS file to a new λ interval and increment and shift it in velocity.

(ii) Perform arithmetic on two homogeneous files (same starting and ending λ's) after correcting for velocity shifts for example. To do this properly, rectified data are best used although the weighting system may overcome some problems if one is working in direct intensity.

(iii) Add a series of weighted, homogeneous files together after correcting for velocity shifts and/or redefining new spectral regions.

(iv) Store this converted file (if it is not to be converted to a ln λ file).

(v) Convert a λ to a ln λ file (or U-file) and store this.

(vi) Stack-plot a series of files.

Note that TSTACK partially parallels COMBINE (see later) inasmuch as both will shift spectra in velocity, convert to a common wavelength region, harmonize wavelength increments, and store the results as new FITS disk records. However, TSTACK will convert the files to ln λ prior to storing them in preparation for use with VCROSS. This is all done automatically once the controlling file has been established. Also the Tektronix stack-plot allows the user to preview the graphs to be plotted on the CalComp with CSTACK.

The nomenclature and general philosophy behind this program is consistent with REDUCE and the related programs. In particular the file-naming convention must be understood. Once again we refer the reader to Paper IV.

PLOTFITS

PLOTFITS is a simple program for making Tektronix plots of FITS disk files (L,F,S,W,I,R and U files). It is also possible to smooth the display and write the smoothed spectrum to disk as a FITS file under its current name or with a new one. By using a file, which we term a master file, containing the names of all the files to be processed, it is possible to have PLOTFITS automatically cycle through various steps. Thus data may be plotted, smoothed, hard copies made, and written to disk without having to tend the terminal once things are underway.

VCROSS

VCROSS is a program which uses wavelength-linearized and rectified data (over a restricted wavelength range) or a ln λ linearized scale to measure radial velocity differences between stars by cross-correlating one stellar spectrum with another. The tool used in this analysis is FOURT (Brenner 1967). The choice of the reference spectrum is arbitrary and can therefore be a velocity standard of similar spectral type, the program star itself, or a synthetic spectrum. (Note: If one uses a synthetic spectrum generate it with the program GENERATE.) The linearized data must be rectified before cross-correlating.

The rectification is very important in that the sharpness of the resultant cross-correlation function is critically dependent on the presence of trends in the continuum. Other techniques needed to enhance this peak are taken from Simkin (1974) and include the initial adding of data to each end of the spectrum (this prevents information being lost when the tapering occurs - see later), normalizing the spectrum to the average intensity and tapering each end of the spectrum by a cosine bell function. After this, additional data in the form of zeroes are added to each end of the spectrum to increase the number of data points to a multiple of 256.

At the suggestion of Johannes Andersen we also taper (cosine bell function) the comparison star Fourier transform. The tapering affects one-twelth of each end of the Fourier transform and results in a sharper c.c.f. peak and a reduction of the background, although this later effect is not always achieved. The amount of tapering is variable and our limited experience shows that a little experimenting is desirable for the best results.

The rectification may be performed by REDUCE (Paper IV, Option 15) or may be done within VCROSS. This latter choice has been included to enable the user to take a 'quick look' and is not intended to replace the more rigorous rectification available in REDUCE, although in fact the identical software is included in VCROSS. As used here, the rectification proceeds automatically and the user must note by the flat or otherwise peculiar appearance of the c.c.f. that a problem exists in the rectification. (As noted above it is possible to do a full 'hands-on' rectification within VCROSS but we can't see the value of it). With the internal rectification remember that one is dealing with W or I files, i.e., those linearized in λ, not ln λ. This should produce some broadening of the c.c.f. although the data may be better because they have not gone through the ln λ conversion, a conversion that may degrade the resolution of sharp-lined spectra because of the generally under-sampled nature of Reticon observations.

It is also possible to convert a linearized λ file to a ln λ file within VCROSS in the same way that it is done in REDUCE, i.e., manually entering wavelengths and increments each time or by automatically generating the wavelengths and increments from linearized λ files. Thus an automatic rectification may be followed by a ln λ conversion.

Wavelength regions of interest can be selected; for example, trying to detect a weak secondary in the wings of a broad hydrogen line is likely to be a futile task and would best be accomplished by the use of narrower lines. Hence, in this case, the hydrogen lines must be suppressed in both the comparison and program star spectra.

Once the c.c.f. is displayed the velocity measurement may be made in a number of ways.

(i) Fit a parabola to the peak.

(ii) Fit a Gaussian or Lorentzian to the profile.

(iii) Fit a number of Gaussian or Lorentzian profiles to the data using VLINE as a subroutine (see §VIII).

In the event that the profile shape is not suitable for fitting by either a Gaussian or Lorentzian function then a standard profile may be generated (see §VIII) and stored in digital form (one-dimensional version of a point-spread function).

As in many of our programs we can use a master file to run VCROSS automatically or semi-automatically. When used automatically parabolic fits to the c.c.f. may be made above a certain height (per cent of the peak height) or Gaussian or Lorentzian fits made to data contained within a window in RV centred on the peak of the c.c.f. Naturally this automatic measurement works only for single components, for more complex c.c.f.'s the measuring process indicated in (iii) above must be followed.

fitting all peaks above a certain level (or all dips below a certain level) with mixtures of profiles, either parabolic, Gaussian, Lorentzian or rotational. Alternatively one may fit these varied profiles between sections of data. These limits are all defined by placements of either the X- or Y-cursors. In making these fits a reliable continuum may be determined if sufficient data are included in the wings defined by the X-cursor placements. Alternatively if only the depth, λ and FWHM are to be calculated then an approximate (but maybe surprisingly good) continuum level is defined by making a histogram of the intensity values at each end of the displayed spectrum and adopting the maximum of the histograms at some mean λ as the two extreme continuum levels and then interpolating between them for the continuum. Obviously this technique is subject to errors but is perfectly adequate for the this task. (Note: If EW measures are made a little more care must be taken). When λ measures are made by using the Y-cursor, the starting values for the continuum level and slope are defined by the end points of the profile. Except for the parabolic profile which may be fitted analytically the other profiles are solved by successive iterations using CURFIT from these initial estimates of depth (height), λ and FWHM. The fit is drawn through the data. The results may be stored in a disk file.

GRENS

Wavelength measures of reduced GRENS spectra may be made within GRENS by fitting parabolas to data contained within boundaries defined by the X-cursor. Alternatively these measures may be made with a single X-cursor setting. These spectra (J FITS disk files) may also be measured with VLINE or VELMEAS. Once a series of spectral features have been made a red-shifted velocity may be calculated based on the best correlation between the measure of unidentified lines and a list of possible ones. An alternative method that could be easily implemented would be to generate synthetic spectra from the measured and expected line list and measure the red-shift by cross-correlating the two.

C. Measure EW, RV, λ, FWHM, $\underline{v}$ sin $\underline{i}$

VLINE

VLINE is an interactive program which enables one to measure λ, EW, FWHM or $\underline{v}$ sin $\underline{i}$ 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 lengths of spectra. Thus one can analyze 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's by integrating areas between the adopted continuum and the spectrum as defined by two cursor placements.

VLINE uses CURFIT (Bevington 1969) to solve a composite function with a maximum of 38 unknowns. CURFIT needs starting estimates which the user provides 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 redundancy at each step to allow one to correct 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 to measure a whole series of spectra automatically.

VLINE can be used in two modes. Mode 1: Line list: Here one uses a list of lines to direct VLINE. The amount of data displayed is governed by the 'line width', a datum is 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 generally beginning at the lowest λ. By default the initial length of the data stream is 901 points but it can be changed. Up to 3000 points can be plotted but the practical limit in plotting and computing time is 901 points.

Used in either of these modes VLINE allows one the choice of 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 we've set, and hence only a part of these data can be used. Also if large stretches of continuum seen to be locally linear are present computing time can be reduced by only analyzing pieces of the spectrum around each line. These considerations alone govern the measuring structure of VLINE as outlined on page 188.

The measuring process is straightforward but time-consuming inasmuch as CURFIT requires starting values of the function parameters (mean position λ_0, FWHM, and line depth d) as well as estimates of the linear continuum-level. These values are directed to VLINE by 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 λ_0 and FWHM 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 datum 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 remarkable 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 at 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. For each line this process results in λ_0, d, FWHM (and perhaps $\underline{v}$ sin $\underline{i}$) and a theoretical EW based on the function parameters and the continuum