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ECHELLE SCANNER DATA REDUCTION SYSTEM

M. R. Hartoog

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Contents

GENERAL INFORMATION

The Echelle Scanner Data Reduction System (ESDRS) is a series of programs designed to reduce data taken with the Echelle Scanner. The main command program is program 10. When the ESDRS disk is bootstrapped there should be a X CALL (10,1) in memory, so simply typing G, RETURN should start the program.

A number of flags are kept in a protected area which indicate whether or not various buffers have been loaded or whether various operations have been performed. Whenever you enter, G, RETURN you will be asked:

HAVE YOU ANSWERED THIS QUESTION BEFORE? (Y or N, ESC=Y)

If you answer N, then all the flags will be initialized. You should always say N the first time you start the program. Subsequently if you restart the program, this way you should answer Y or ESC so that all the flags are not reinitialized.

In general, you can CTRL-C the program at anytime and restart it simply by typing G, RETURN. This should restart the command program and ask for a new command. All of the "buffers" used in the program such as the Quartz Buffer are stored on the program disk. All of the important flags are stored in the protected area which is preserved over re-bootstrapping. In the following, "quartz" referers to continuum data from a quartz-iodine lamp, used for removing image-tube irregularities. "Tungsten" is synonomous.

Thus you can re-bootstrap the program disk at any point without loss of information if you then restart in group 1 of program 10 and answer "yes" to the question described above.

When the program is started it will display the list of commands. These commands are described in detail below.

Reduction of Data

There are now three different reduction procedures available. In the first of these, called "Normal" or "Old" reduction procedure, one first adds all the sky or dark scans. Then each star scan is scrunched after an appropriate background subtraction and quartzing. "Quartzing" means dividing data scans by a "quartz" continuum scan, and "scrunching" refers to the process of channel combination used to produce final scans that are linear in wavelength. After scrunching, the scan lines are added up, shifted to correct for the Earth's orbital and rotational velocities, and then summed with previous star scans. After all star scans have been added together, the sum is transfered to a reduced data tape.

The second method, generally called the "Special" method, is similar to the Normal method except after scrunching the scans, the scan lines are not added together. The sum for each scan line is kept separate; all lines are shifted to correct for the Earth's velocity before summing. This then allows a special line flattening routing written by G. Herbig to be used before the scan lines are added together.

The third method, known as the "New" method, is quite different from the first two. Raw star and sky (or dark) data are added up for each scan line. When all the raw data has been summer, the sky is subtracted and the data is quartzed. Then this sum is scrunched and all scan lines added up. An average shift to correct for the Earth's velocity is made and the result is then transfered to a reduced data DECtape (or IBM tape).

It is generally recommended that the last method, the "New" method, be used. Because of the sequence of operation used in this method, truncation errors (due to the interger arithmetic of the PDP-8) are minimized. This keeps unnecessary smoothing of the data to a minimum. The new method is also the only one with which the scattered light correction procedure works.

Each of these procedures is described below.

Normal Reduction Procedure

1. Edit necessary Log information.

Stellar scans must have the following log information:

Dwell time, RA, Dec, Epoch, U.T. time, UT date, H.A., log ID code.

Quartz scans, fringe scans, and Th scans need not have any log information, although it is recommended so that data tapes are fully self-documenting. Log ID codes are as follows:

S star data on all scan lines

D star data in half of scan lines, sky/dark in other, i.e., double slit data

K sky/dark data in all scan lines .

An N after the above signifies the first scan of a new object, e.g.,

SN, DN, KN.

NOTE: Sky scans (or dark scans) must have log information like scans on stars. This could be identical to the log informaiton for the preceding or following star scan or it could be real information for the time the scans were taken if star and sky scans were alternated. The RA and Dec should be the sams as the stars.

2. Set the switch panel according to the switch labels:

1,1 Origin of data:

0. Raw data tape (unit 7)
1. Star sum buffer
2. Sky sum buffer
3. Quartz buffer
4. Reduced data tape (unit 6)
5. Scratch buffer #1
6. Scratch buffer #2
7. Erase CRT/Advance Calcomp

1,4 Size of slit

(used by scattered light function)

0
1. 200 MICRON
2.
3. 400 MICRON
4.
5.
6.
7.

1,7 Order of polynomial for fitting data during scrunch:
1 to 8, top to bottom

1,10 CRT offset

0. 700
1. 600
2. 500
3. 400
4. 300
5. 200
6. 100
7 0

2,1 No. of scan lines

0. 2

1. 4

2. 8

3. other

2,7 Plot mode

0. Sum of all lines

1. Each line

2. Selected lines

3.

2,3 Equivalent width scale factor

0. 1

1. 2

2. 4

3. 8

Toggle Switches: If up, then

3,7	3,6	3,5	3,4	3,3	3,2
Emission lines			Print tables during scrunch preparation	Put output on IBM	Take input from IBM

4,12	4, 11	4, 10	4, 9	4, 8	4,7
Don't advance calcomp after a plot	Print labels for plots	Assume dimensions for old Fabry-Perot etalon	Use center scan lines only	Enable Atmospheric Line Remover	Supress Velocity Corrections

3. Load Quartz buffer (Option #16)

4. Prepare Lambda Calibration (#17)

5. Prepare Scrunch table (#18)

6. Erase Sum buffer (#19)

7. Sky or Dark Sum (#20)

   - enter all sky (or double slit) scans. Enter ESC when finished.

8. Scrunch Add with Sky sub (#21)

   - enter all Star (or double slit) scans. Enter ESC when finished.

9. Buffer Transfer (#11)

The star sum buffer (SM) to a scan on a reduced data tape (TR).

If all scans have the correct log ID codes, then the Batch Scrunch function (#22) will automatically perform steps 5 through 8 above.

Special Reduction Procedure

Steps 1 through 4 are the same as for the normal reduction method.

Repeat steps 5 to 9 for each star to be reduced.

5. Erase Sum Buffer (#19)
6. Sky or Dark Sum (#20)

   - enter all sky (or double slit) scans. Enter ESC when finished.

7. Special Scrunch Add (#28)

   - enter all star (or double slit) scans. Enter ESC when finished.

8. Flatten Scan lines (#29)
9. Combine and Store (#30)

There is no batch reduction program available for the special method.

NOTE: Double slit data must have a log ID code of D or DN to be treated correctly.

The Scattered Light Correction

"Scattered light" is produced by the wings of the instrumental profile. It is assumed that the dominant contribution to these wings comes from the image tube chain and the dissector. This means that the instrumental profile will be independent of wavelength.

Correcting for scattered light involves a deconvolution to remove the effects of the instrumental profile. The most straightforward method of doing this (in principle) is in the Fourier domain, but unfortunately, Fourier transforms are beyond the capabilities of a PDP-8. Furthermore, one can never completely remove the effects of an instrumental profile because of noise limitations. It is necessary to filter the Fourier transforms to reduce high frequency noise. The resulting "corrected" spectrum has an instrumental function which is the transform of the filter function.

The correction procedure used in ESDRS is much simpler. Figure 1 shows

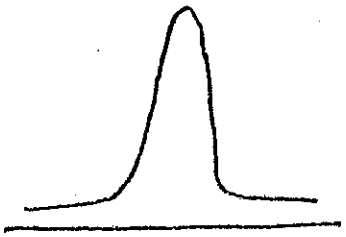

fig. 1

fig. 2

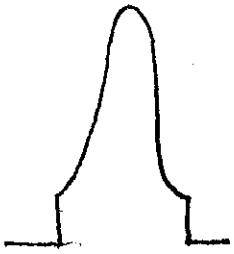

fig. 3

a profile with exaggerated wings. If we zero the central section of this profile as shown in Figure 2 and convolve this with the infinite resolution spectrum and then subtract this from our observed spectrum, we would end up with a spectrum with an instrumental profile like that shown in Figure 3. We would have removed the effect of the wings on our data.

Clearly we cannot do this because we do not have the infinite resolution spectrum available. Instead, we start with the observed spectrum as an approximation and iterate until the procedure converges. Since the profile in Figure 2 washes out any sharp features in the spectrum, the use of a spectrum with an instrumental profile like that shown in Figure 3 rather than the infinite resolution spectrum should be unimportant.

ESDRS has a buffer which can hold 8 scatter light functions of the form shown in Figure 2. Which one of the buffers is used is selected by switch 1, 4 and toggle switch 3, 8 enables the scattered light correction procedure. NOTE: Scattered light corrections only work with the "New" reduction method.

IBM Tape

The entire reduction program was written to allow IBM tape to be used interchangeably with Dec tape as much as possible. Switch 3, 2 controls whether input comes from Dec tapes or IBM tapes. Switch 3, 3 controls whether output goes to IBM tape.

Most commands read these switches and determine whether to take their input from Dec tape or IBM tape. A few functions, such as the Log Edit function, can only work on Dec tape and so they ignore these switches.

All of the IBM tape I/O is done through a single program written by Bob Kibrick. It is essentially the same program that does IBM tape I/O in the 32K data taking program. This program keeps track of the current tape position and the last scan on the tape at all times. The four pointers used to keep track of this informaiton along with the flag that indicates if an IBM tape is mounted are located in the protected area and therefore

are preserved over re-bootstrapping. Since these pointers have to be updated after each IBM operation, a CTRL-C during an IBM tape read or write could leave these pointers in an incorrect state. Therefore, the CTRL-C monitoring is disabled during an IBM tape operation. The computer will simply ignore a CTRL-C during an IBM tape read or write. If for some reason you wish to execute a CTRL-C during an IBM tape operation and the computer fails to respond, hit the STOP button on the PDP-8 (not switch 3, 10), then depress Load Address and START. This will restart the computer at Ø2ØØ octal which is the equivalent of a CTRL-C. After doing this it must be assumed that the IBM pointers have been clobbered and the IBM tape should be remounted (command #1) before any more IBM tape operations are performed. After re-starting the computer at Ø2ØØ octal the normal CTRL-C monitoring will not be restored. However, simply typing G, RETURN will restart the command program which always restores normal CTRL-C monitoring.

IBM Tape Organization

IBM tapes are organized into Files. A file is a series of records terminated with an End-of-File (EOF) mark. Usually the end of the data on the tape is indicated by two EOF marks without any data records between them. Unlike Dec tape, data can only be written at the end of an IBM tape. If a data record is written in the middle of an IBM tape, in general all data after that record on the tape is lost. For this reason, the IBM tape handling routines always write information to the end of the tape or at least where it was told the end of the data was when the tape was mounted.

When a tape is mounted using command #1 it will ask how many files are on the tape. If another scan is written to the tape, it will be written to scan Ø of the next file on the tape. If you wish to add more scans to the last file on the tape, rather than starting a new file, use the open last file command (#3).

As mentioned above, a file consists of a series of records. A raw data scan (4096 channels) takes up 4 records, a reduced scan (2048 channels) takes up 2 records. A maximum of 4096 records may be contained in a single file, so 1024 raw data scans or 2048 reduced data scans may be contained in a single file. A maximum fo 4096 files may be contained on one IBM tape (this is the software limit; it doesn't mean there is room for that many files on an IBM tape).

Within a file are scan numbers as on a Dec tape. The first scan is scan Ø, the next scan 1 and so forth. How the record number is computed by ESDRS from this scan number depends on whether a raw or reduced scan is expected. Therefore, raw and reduced scans should never be mixed in the same file. It is perfectly all right to have raw and reduced scans in different files on the same IBM tape.

After every write operation on an IBM tape, two EOF marks are written and then these marks are backspaced over. Therefore, unless some catastrophic error occurs (like the physical end of tape) during the write, the tape should always be properly terminated and can be physically dismounted without any danger of leaving the tape improperly terminated.

Command 0 - Form Command Loop

Will ask on teletype for a series of command numbers which will be preformed in a continuous loop. Terminate loop with a command of Ø which will begin execution of the loop. To stop execution of the loop and return to normal command mode, type CNTL-C followed by G, RETURN. A maximum of 29 commands may be put in a single command loop.

Command 1 - Mount IBM Tape

This command is used to set the IBM flag to indicate that an IBM tape is mounted and to initialize the locations used to keep track of the tape position. When this command is given the tape should be mounted and the drive "ON LINE". The tape will be rewound if it is not already positioned at the load point. The command then asks for the number of files (not records) on the tape. If the answer is zero, then the tape is assumed to be empty and the first 4 feet will be erased. Before doing this, the user will be asked to confirm that the tape is empty. If the user's answer is anything other than "Y", he will be asked to confirm that the tape is empty. If the user's answer is anything other than "Y", he will be asked again for the number of files on the tape.

NOTE: Following a tape mount, the next scan written to the tape will be scan 0 of the file one greater than the number of files on the tape the user entered when the tape was mounted. Example: If the user said there were 3 files on the tape when it was mounted, then the first scan written will be scan 0 of file 4.

If the user wishes to add more scans to the last file on the tape (file 3 in the above example), he should use the open last file command (No. 3).

2. Close IBM File

This command allows one to close the last file on an IBM tape so that the next scan written to the tape will go to a new file. For example, if the last scan written to the IBM tape was scan 10 of file 3, then after a close IBM file the next scan written to the tape will be scan 0 of file 4. NOTE: If you do not wish to write another file on the tape it is not normally necessary to use this command. The appropriate number of end-of-file (EOF) marks are automatically written on the tape after every write operation. If for some reason you suspect they may not have been written, this command will insure that the tape is properly terminated with two EOF marks.

3. Open Last IBM File

This command allows one to add more scans to the last file on an IBM tape instead of writing scans to a new file each time the tape is mounted. The command causes the tape to position itself to the end of the last file. This can take a long time if there is a large amount of data already on the tape, like 15 or 20 minutes!!

NOTE: Writing the data to a new file each time the tape is mounted does not significantly reduce the search time to each the end of the data on the tape.

4. Tape Copier

This command invokes the general purpose tape copier. It may be used to copy either raw or reduced scans from Unit 7 (or IBM tape) to Unit 6 (or IBM tape). Switches 3,2 controls whether input is from Dec tape Unit 7 or IBM tape. Switch 3,3 controls whether output goes to Dec tape Unit 6 or IBM tape.

When the command is mounted the user will be prompted to set switches 3,2 and 3,3 and will then be asked whether he wishes to copy reduced (RED) or raw (RAW) data scans. The program makes no attempt to verify that the scans being copied are of the type specified. If the wrong type is specified, the scan numbers will be computed incorrectly and the wrong data will be copied.

The user will then be asked for a input scan range to copy. If the input is from IBM tape, a IBM tape file and scan range will be requested.

If the output is to Dec tape, Unit 6, the user will be asked for a starting scan number. The first scan copies will be put in this scan. Subsequent scans, if any, will be placed in succeeding scans. If the output is to IBM tape, the scans will be written to the end of the tape.

Note: 1) Never mix raw and reduced scans on the same dec tape or in the same file on an IBM tape. This is almost certainly to result in disaster.

2) It is possible to copy scans from IBM tape to IBM tape with this command. This results in scans from some file being copies to the end of the IBM tape.

5. Raw Data Log List

This function is similar to the Log List function in the data taking system. It will ask for a scan range (IBM file and scan range if switch 3,2 is up). For each scan in that tange, the ID information will be listed on the teletype.

6. Raw Data Log Edit

This function allows one to edit ID information on raw data tapes. When the program is run, the user is asked for a raw data scan number.

This scan is read into the buffers and the ID information is displayed on the CRT. Each ID item is numbered 1 through 17. The program will then request an item number to edit and a new value for this item. After each item has been edited, the ID information is again displayed on the CRT. One can continue editing items until all the ID information is correct. Then hit ESC instead of another item number to store the information on the tape. If you hit CTRL-C and type G return instead, the information will not be stored back on the tape. After storing the information back on the tape, the program will request another dec tape scan number. Hit ESC to quit, or enter a scan number to edit another scan.

7. Reduced Data Log List

This function is similar to the raw data Log List. It lists ID information for reduced scans. It requests a scan number range (IBM file and scan number range if switch 3,2 is up).

8. Compute Hour Angles

This function asks for a first and last scan number and for each scan between those limits computing the hour angle using the information in the ID areas. This hour angle is then stored in the ID area and the scan rewritten to Unit 7. For this function, Unit 7 must be write enabled. This function will not work on IBM tape (switches 3,2 and 3,3 are ignored). The following information from the ID areas is used to compute the hour angle: UT Time and Date, Right Ascension and Declination and Epoch.

The routine used to calculate the Local Sideral Time for Mt. Hamilton has been checked and is accurate to better than ± 1 second. Coordinates are processed to time of observation. Since UT time are recorded to nearest 1 minute, Hour Angles should also be accurate to ± 1 minute.

9. Display Buffer

This function displays buffers or scans from reduced or raw data tapes on the CRT. The source of the scan is read from switch 1,1 , the mode to plot it from switch 2,7 , and the Y offset from switch 1,10.

For raw data (scan from tape unit 7, Quartz buffer or either scratch buffer) either the sum of all scan lines, or all scan lines, or only selected scan lines can be plotted. If more than one scan line is plotted, the lines will be offset by 100 units on CRT. For reduced data scans (either sum buffer or scan from reduced data tapes) switch 2,7 will be ignored.

10. Calcomp Buffer

This function plots data from a buffer or scans from reduced or raw data tapes on the Calcomp. The source of the scan is read from switch 1,1 and the mode to plot it from switch 2,7.

For raw data (scans from tape unit 7, Quartz buffer or either scratch buffer) either the sum of all scan lines, or all scan lines, or only selected scan lines can be plotted. If more than one scan line is plotted, the lines will be offset by 1 inch. For reduced data scans (either sum buffer or a scan from reduced data tapes) switch 2,7 will be ignored.

The program asks for the following information:

1) X scale factor in points per step. This may take on integer values.

2) The relative Y scale factor. The program automatically scales the data. This scale factor multiplies the auto-scaling scale factor. A value of 1,

the default, will produce the plot with auto-scaling. A value less than 1 will make the plot larger. A value greater than 1 will make it smaller. The same auto-scaling routine is used by the Display command, so one can check what it will do with a given scan.

3. The Y offset in inches. The zero level is usually at the bottom of the page. This offset can move it up or down. Positive offsets move the zero level up on page.

When the last question is answered, the Calcomp should be turned on with pen zeroed at the right hand side of the page. The plot will start almost immediately. When the plot is finished the Calcomp will advance a few inches and should be set up for another plot. If the pen was zeroed on an inch mark on paper, it will again be zeroed on an inch mark.

If you want to make more than one plot vertically offset by some amount, put switch 4,10 up. In this case the pen will return to its origin after finishing the plot instead of advancing a few inches. To get the Calcomp to advance, one can generate the last plot with switch 4,10 down or use the advance calcomp option on switch 1,1.

11. Buffer Transfer

This program allows one to transfer scans between tape and various buffers. The program lists codes for the available buffer or tape on the CRT. It then asks for the input code. If a tape is requested, the scan # will also be requested (file, and scan # on IBM tape). The scan from the requested input buffer or tape will then be read into core. Then an output code will be requested. On a tape a scan # will also be requested (on IBM tape no scan number is requested since all scans are written to the

end of the tape). The program then writes the scan from core to the requested buffer or tape.

Important Notice: Raw data scans and some buffers are 4096 channel scans. Reducedscans and some buffers are 2048 channel scans. If a 4096 channel scan is moved to a 2048 channel buffer or a reduced data tape, the last 2048 channels will be lost. On the other hand, no data will be lost moving a 2048 channel scan to a raw data tape.

Star Sum buffer:	2048 channels
Sky Sum buffer:	4096 channels
Quartz buffer:	4096 channels
Scratch buffer 1:	4096 channels
Scratch buffer 2:	4096 channels
Raw Data Tape (7):	4096 channels
Reduced data tape (6):	2048 channels

12. Wild Point Remover

This program may be used to remove bad points from raw scanner data; either high or low points may be removed. It is a very good idea to make a backup copy of the raw data tape before using this function. Once the data is written back onto the tape, it is impossible to undo the changes to the data. As a reminder, the program always gives a warning that a back-up copy should be made.

When started, the program asks for a scan number; this scan is read into memory. The first scan is displayed on the CRT and the user is asked to mark a bad point. If the bad point is high, then the user places the cursor at the approximate X position, but below the point and uses the 3,11 switch. If the bad point is low, then the user places the cursor at the approximate X position but above the point and uses switch 3,12.. The high (low) point will be reset to the average of nearby points which are below (above) the Y level marked with the cursor. The data will then be replotted on the CRT and the user will be asked to identify another bad point. If there are no remaining bad points the user should hit switch 3,10 to go onto the next scan line. When all scan lines are finished, the scan will be written back on the disk or tape. Unit 7 must be write enabled for this purpose.

13. Setup Atmospheric Line Standards

This function allows each scan to be divided by a scan of a B star to remove telluric lines, but this function does not do any of the divisions. It simply sets up the B star scans which the data will be divided by during the scrunch processes if switch 4,8 (enable atmospheric line remover) is up.

Two modes of operation are possible: each scan may be divided by a given B star scan, or an interpolation between high and low airmass scans can be made, corresponding to the airmass of the observed program star.

To use this function follow these steps:

1. Load Quartz buffer, prepare Lambda calibration and load scrunch table.

2. Reduce the scans of the B-star or high and low airmass B-stars (scrunch Add Star, sky or double slit, etc.) with switch 4,7 (surpress velocity corrections) up and switch 4,8 (enable atmospheric line remover) down.

3. With the unshifted scan of B-star or stars on unit 6, invoke this function. It will ask for a Low Airmass standard scan and a high air mass scan. If you only have a single scan enter it as the low airmass standard and hit ESC for the high airmas standard.

4. Now reduce the program scans with Switch 4,7 (surpress velocity correction) down and switch 4,8 (enable atmospheric line remover) up. If you use batch scrunch it does not hurt anything if the B-star scans are reduced. They should come out flat.

14. Batch Log Edit

This command is specifically designed for inserting log information on tapes which do not have this information. It can also be used to correct a mistake that was made in many scans (i.e., incorrect data entered or wrong RA and Dec, etc.).

The Log information is divided into three groups. The first group is the Setup information. This includes UT Date, Echelle, Cross disperser, Focus, Dissector Voltage, Slit Width, Central Wavelength and Seeing. It

is assumed that this information will be the same for more than one star. The user will be asked for all the setup information first. Entering ESC for any item means that you want the information for that item left as it is in the ID area of each scan.

Next, the user is asked for the scan number range to process. If any star information described below is to be modified, only the scan number range for a single star at a time can be processed. If none of the star information is being modified, then the whole tape can be modified if desired.

The user is then asked for star information. This information is assumed the same for all scans of a given star and includes Name, RA, Dec and Epoch. Again entering ESC means that the information already in the ID areas will not be changed for that item.

Now the user will be asked if he/she wishes to edit the individual scan information. This includes Log ID Code, UT time, and H. A. If the user answers Yes (Y) then for each scan the user will be asked for this information. Again entering ESC will cause the item on that scan to remain unchanged. If the user indicates he/she does not want to edit individual scans, then the information in this group will remain unchanged.

After all the specified scans are edited, the user will be asked whether he/she wishes to change the setup information. If not, then the user will be asked for a new scan # range and a new set of star information, etc. If the user answers Yes (Y) then he/she will first be asked for new setup information.

To stop the editing process, enter ESC when asked for the first input scan.

Note: Because of the way the date is encoded in the ID area, if only part of the date (e.g., the day) needs to be changed, the full date still needs to be entered. If you reply ESC to the month, you will not be asked for the day and year and the whole date will be unchanged.

16. Load Quartz Buffer

This function sets up a normalized quartz calibration. It will ask for scan numbers of quartz scans. After last scan is entered, hit ESC cause the normalization. A separate quartz scan is prepared for each scan line. These normalized quartz scans are displayed briefly on the CRT.

17. Lambda Calibration

This function does a wavelength calibration and saves the coefficients in an internal buffer.

The function first asks for scan of the interference fringes. These scans are quartzed, and normalized so the average value in each scan line is the same. All of the scan lines are plotted on CRT and a threshold is set with the cursor. This threshold is for coarse fringe finding only. Any peak above this threshold will be considered a fringe and an exact position will be found for it using the first moment peak finder. Then each scan line, offset slightly, is plotted and the position of fringes that have been found in all scan lines are marked and numbered.

At this point, the user is asked if everything is OK. If the user answers NO, then the program starts over. Future versions may contain an editor to allow correction of possible errors.

The program next asks for the approximate wavelength of the first fringe. This is used to calculate the fringe spacing and only need be given to a few A accuracy. From the fringe spacing a relative wavelength system is set up with an arbitrary zero point. Then for each scan line a polynominal dispersion relation of the form

$$\lambda_{rel} - YM = C_o + C_1(X - XM) + C_2 (X - XM)^2 + \ldots.$$

where λ_{rel} is the relative wavelength, X is the channel number, YM is the mean λ_{rel} for all fringes, XM is the mean X for all fringes, and C_o, C_1, C_2 etc are the coefficients. The order of the polynomial used is controlled by switch 1, 7; a minimum of (order+2) fringes must be measured. Versions earlier than 3.1 would only do orders up to 5th. Versions 3.1 and later will do orders up to 8th. After the fit for each scan line, the coefficients and residuals are displayed on CRT and the user is asked if they are OK. If the user answers NO, switch 1,7 will be read again and the fit will be done over. Future versions may contain an editor.

Next the user is asked for the comparison scan. If the user enters ESC, then no zero point for the relative wavelength system is found. A scrunch table may still be calculated and scans linearized, but the origin of the wavelength system will be arbitrary.

If a comparison scan is entered, then it will be quartzed, and normalized so each scan has the same total number of counts. Then the first scan line will be plotted on the CRT and the user asked to point to a line at the theshold which should be near the base of the line. The program will then measure the position using the first moment peak finder of the line in each scan. If an error occurs while attempting to measure a line the message PEAK FINDING ERROR will be printed and the user will be asked to try again. This error can occur because 1) there is no line where the user pointed. 2) The line is too close to ends of scan; 3) Some other mysterious reason. After a line has been measured in all scan lines, then the user is asked to enter the wavelength or ESC to measure the line over or measure another line instead. After as many lines as desired have been measured the user should press switch 3, 10 instead of 3, 11. Then depending on the number of lines that have been measured, the program will take one of the following actions: 1) If no lines have been measured, then program will proceed as described above for the case where no comparison spectrum was available. A scrunch table can still be prepared and data linearized but the zero point will be arbitrary. 2) If one line was measured then an average zero point for all lines (w(o)) and independent zero points for each scan line will be determined. 3) If two lines were measured, then an overall zero point and a linear correction factor C will be determined:

$$\lambda = W(o) + C \cdot \lambda_{rel}$$

where λ is the wavelength, λ_{rel} the wavelength on the relative system set up using the fringes, and W(o) is the zero point. The factor C corrects for any error in the assumed fringe spacing and should be close to unity. After this overall correction of the wavelength scale, independent zero points will be determined for each scan line. 4) If three of more lines are measured then a least squares fit to the linear relation above is made for the average λ_{rel} of each line. Then an independent zero point is determined for each scan line. In this case errors will be given for all the coefficients.

In cases 2, 3, and 4 above, after displaying the coefficients and residuals on the CRT, the program will ask if the result is OK. If the user answers yes, the coefficients are stored and the wavelength calibration is finished. If the user answers No, one enters a simple editor which allows one to change the wavelength of a line or delete a line. Lines once deleted cannot be recovered. After editing, the coefficients will be redetermined.

NOTES: 1) At the moment there is no way to average wavelength calibrations.

2) If switch 3,4 is up, the tables will be printed on the teletype rather than on the CRT. This can be quite time consuming.

18. Prepare Scrunch Tables

This function prepares the scrunch tables necessary to linearize the data. The one restriction on the scrunch table is that one must end up with fewer channels than one started with (for 2 line data, <2048;

for 4 line data, <1024; for 8 line data, <512). The scrunch table however can extend beyond the range of available data or not completely cover it. The step size used to prepare the scrunch table also controls the dispersion at which it will be plotted on the Calcomp plotter. The Calcomp takes 100 steps per inch, thus if one desires plots at 1 A/inch, one should use a step size of 0.01 Å. If one desires 2 A/inch, then a step size of 0.005Å should be used. The step size can only be given to the nearest 0.0001Å (0.1mÅ).

When this function is executed, it will find the available range of data and determine the smallest step size which still allows all the data to fit into the number of available channels. It will then print the available range and this minimum step size and ask whether this is OK. If the user answers yes, the scrunch table is prepared using those parameters. If the user answers no, then the user may enter his/her own starting wavelength ending wavelength and step size (all in Å). These will be checked to insure they do not require more than the maximum number of points and the user will again be asked if they are OK. When he/she answers YES, the scrunch table will be prepared. This takes about 1 minute.

19. Erase Sum Buffer

This function erases both the star and sky sum buffers and initializes the respective ID areas.

20. Sky or Dark Sum

This command is used to sum all of the sky or dark scans to be used in the reduction of a star. The sum for each scan line is kept separately. The only ID information need in the dark or sky scans is the dwell time and the ID code. If the ID code is D or DN then the program will assume the data is double slit data. In this case only the slit with the fewest total counts will be added into the sky buffer (the sum for each slit is kept separately). If the ID code is anything other than D or DN, then the program will assume it is single slit data and sum all scan lines into the sky buffer.

When all the sky or dark scans have been summed, enter ESC to return to the command program.

21. Scrunch Add with Sky Subtract

This function subtracts off the appropriate sky or dark count background and then scrunches (i.e., makes the data linear in wavelength a series of scans on a star). The following ID information must be correct in each scan: Dwell time, RA, Dec, Epoch, U.T. time, U.T. Date, H.A. and Log ID code; this information will be used to compute the corrections for the earths' rotational and orbital velocity. Unless switch 4,7 is up, the scans will be shifted to take out both the earths' orbital and rotational velocity. Thus any remaining Doppler shift will be the heliocentric radial velocity.

If the Log ID code is D or DN, the data is assumed to be double slit data and only the slit wilth the larger number of counts is processed. If the Log ID code is any other code, the data will be

treated as single slit data.

In scrunching the data the following steps are taken: 1) The sky is scaled by the ratio of the scan dwell time to the total sky dwell time and subtracted for each scan line. 2) The scan is quartzed. 3) Each scan line is scrunched to produce a spectrum linear in wavelength. 4) The linearized spectra from all the scan lines are added together. 5) The correction for the earth's orbital and rotational velocities are computed. 6) If the atmospheric line remove is enabled, then the specturm is divided by a β-star spectrum to remove atmospheric lines. 7) The spectrum is shifted to remove the earth's motion. 8) The spectrum is added to the sum buffer.

NOTES: 1) If switch 3,4 is up, the information normally displayed on the CRT (RA, Dec UT Time and date, Julian data, orbital velocity corrections, etc) will be printed on the teletype instead.

2) If switch 4,7 is up, the appropriate shift to remove the earths motion will be computed, but the shift will not be made.

3) If switch 4,8 is up, the spectrum will be divided by an atmospheric line standard before the shift takes place. This is intended to remove atmospheric lines. For details on how to use this feature, see the Setup Atmospheric Line Standard command (#13).

22. Batch Reductions

This function automatically performs the basic reduction sequence (Erase Sum buffer, Sky Sum, Scrunch Add, Output to reduce scan) for

scans which have the appropriate Log ID codes. The Log ID codes recognized by this program are

S - Star Scan - Single slit

SN - first scan of new object, starting with star

K - Sky or dark scan - single slit

KN - first scan of new object, starting with Sky

D - double slit data

DN - first scan of new object, double slit

Any other code will cause the scan to be ignored.

When the function is executed it first requests a reduced data scan # to begin storing the output reduced scans (if switch 3,3, output to IBM tape is up, then this step is skipped since output to IBM tape always goes to the end of the tape.). Then the program will ask for a starting and ending raw data scan no. (if switch 3,2, input from IBM tape, is up then an IBM file no. will also be requested.).

The program makes two passes through the scans for each star. On the first pass sky or dark integrations are summed. On the second pass the star scans are reduced and summed. After the second pass, the result is written out to unit 6 (or IBM tape) and the sum buffer is erased.

When the program reaches the end of the input scan range on its first pass through the data, a new scan range (presumably on a new Dectape) will be requested. The program will then continue its first pass through this new Dectape until it reaches the first scan of a new object. If the end of this second dectape is reached before the first

scan of a new object is found, then a scan number range on a third Dectape is requested, and the first pass continues on this Dectape. The scans of a single object can be on as many as 100 Dectapes. When the first scan of the new object is finally reached, the program will begin its second pass through the data. To do this it will request that Dectapes be remounted at appropriate points.

When the program reachs the end of the last Dectape on its first pass through the data and requests a new Dectape, enter ESC and it will then make its second pass through the last object before returning to the command program.

NOTE: Switches 3,4; 4,7; and 4,8 function as described under "Scrunch Add with Sky Subtract."

Recommendations: To avoid confusion in mounting and remounting Dectapes it is recommended that all the scans to be reduced be copied into one IBM file. If this is not possible or desirable, then it is highly recommended that the raw data input be a floppy disk and the output be a Dectape. If the raw data input (Unit 7) is a Dectape, a great deal of time will be spent rewinding the Dectapes.

23. Batch Calcomp Plot

This function allows a number of reduced scans to be plotted rapidly using the same X and Y scale factors and Y offset. Optionally gummed labels with the name, date, starting wavelength and scale factors may be printed if switch 4,11 is up.

When this function is invoked, it will ask for the X scale, relative

Y scale and Y offset for all scans to be plotted. The X scale factor is in steps per point. This may take on any integer value (1,2,3, etc) or integer fractional value (1/2, 1/3, 1/4, etc) in which case 2,3,4, etc points will be averaged for each step of the calcomp. The linear dispersion in Å/inch which results depends on the step size used to prepare the scrunch table. The Calcomp takes 100 steps per inch. If labels are printed, they will give the X scale factor for each plot in Å/inch.

The relative Y scale factor multiplies the scale factor determined by an auto-scaling routine for each scan. The auto scaling routine adjusts the scale factor so that the peak channel will occur about 6 inches above the zero level. Since the scale factors are integers, in scans with a low number of counts, the scaling can be rather bad. Also one bad channel can cause the data to be plotted at a very small scale. A value of 1, the default, for the relative scale factor causes the plots to be produced at the scale produced by the auto scaling routine. Values larger than 1 will cause the plot to be smaller. Values less than one will cause it to be larger.

The Y offset is entered in inches. Positive offsets move the plot up. Negative offsets move it down. A value of zero will cause the zero level to be at the bottom of the page.

At this point the program will prompt the user to enter the special tractor feed gummed labels and put switch 4,11 up if he wants them. All subsequent messages are printed on the CRT.

At this point the user should also set up the Calcomp with the pen

adjusted at the line on the right side one inch from the margin, and in the "up" position. If the user centers the pen on an inch line, then all plots will start on an inch line.

When the user indicates the calcomp is ready by hitting ESC, the program will ask for a scan # range on the CRT (an IBM file and scan # range if switch 3,2 is up) and proceed to plot that range. If the offset is zero or positive, a line at the zero level will also be drawn.

When the scan number range is plotted, another will be requested. At this point another reduced data dectape could be mounted, for example.

24. Reduced data Add, Sub, etc.

This program allows one to manipulate reduced data. It is possible to add, subtract, multiple or divide two scans, a scan can be multiplied by a constant or a scan can be shifted to the laboratory rest velocity using the velocity measured by the Measure Radial Velocity function (#37). When started, the program lists the function codes to select which of these operations is desired. It then asks for a function code and one or two input scan #'s. After the function is completed, the data is displayed on the CRT and the user is asked for a reduced scan (unit 6) on which to save the result.

25. Load Star to Quartz Buffer

This program can be used to load the quartz buffer with observations of a bright star or to allow dark count subtraction in the regular quartz observations. The program first asks for a series of star (or double slit) scans. These are added into the star sum buffer (or star and sky

sum buffers if ID code is D or DN). Use ESC when all of the star scans have been added. The program will then ask for sky or dark scans. These are added to the sky sum buffer. The listis again terminated with an ESC. For double slit data where there are no separate sky scans, just hit ESC on the first request for a sky scan. When the user hits ESC, the program will subtract the sky from the star and transfer the result to the quartz buffer. The results are briefly displayed on the CRT.

NOTES: 1) This program may be used to approximately remove atmospheric features.

2) Dead time corrections are applied to the data on a scan by scan basis.

26. Load Scattered Light Function

This program is used to load the scattered light buffer using laser line observations. Read page 7 for an overview of the scattered light correction procedure before attempting to use this program.

One first adds up a series of laser line scans; use ESC to end. Then a series of dark scans are added, again ending with an ESC. The dark will then be subtracted and divided by the quartz scan. All scan lines are then added up and displayed on the CRT. At this point the user is asked if a logarithmic Calcomp plot of the profile is desired. The vertical scale of this plot will be 2 inches per decade. Next the profile will be made symetrical and displayed again. The user will be asked to hit RETURN to continue. If eight scan line (512 channel) data was used, it will be converted to 1024 channel data and the user is

again asked to hit RETURN. Next the data is rescaled so that the convolution will be properly normalized and then the user will be asked for the number of channels to erase. After the number of center channels requested has been erased the result is displayed on the CRT and the user is again asked for the number of channels to erase. The erasure is non-destructive so that fewer channels may be erased on the second try than on the first. When the user is satisfied with the number of channels erased in the profile center, he/she should hit ESC. The profile will then be converted to a 256 channel function and the user will be asked in which of eight positions he/she wishes to store the results.

27. Special Scrunch Add

This is a special version of the scrunch add with sky sub (#21) command. It keeps the scrunched sum for each scan line separate, so that the flatten scan line command can be used. The regular sky or dark sum (#21) is used first.

28. Flatten Scan Lines

This program fits Chebyshev polynomials to the shape of each scan line in order to flatten the lines. It can only be used if the data has been summed using the special scrunch add (#27) function. This command will only work with 4 scan line data.

29. Combine and Store.

This command combines the scan lines and stores them on a reduced data Dectape (or IBM tape). It is intended for use after the Flatten Scan Lines (#28) function. It should not be used with the normal or new reduction methods.

30. New Add Star (or Double)

This command is used to sum all the star (or double slit) scan on an object. No reduction is done except for a dead time correction. If the Log ID is D or DN, then the data is treated as double slit data and the large scan is added to the star sum and the smaller scan to the sky sum. Any other slit code causes both scans to be added to the star sum.

31. New Add Sky

This command causes scans to be added to the sky sum buffer after a correction for dead time.

Note: This command should not be used with double slit data; the New Add Star Command (#30) automatically adds up the sky sums for this case.

32. New Reduce and Store Scan

This program reduces and stores the scans added into the star and sky sum buffers by commands 30 and 31. The sequence of operations is as follows:

1) Sky subtract. - scaling the sky scans if necessary.
2) Divide by Quartz.
3) Correct for Scattered light if switch 4,8 is up.
4) Scrunch.
5) Apply heliocentric corrections (unless switch 4,7 is up).
6) Store on a reduced data scan (unit 6).

33. New Batch Reductions

This function automatically performs the basic reduction sequence (Erase sum buffer, New Add Star, New Add Sky, New Reduce and Store) for scans which have the appropriate Log ID Codes. The Log ID codes recognized by this program are

S - Star scan - Single slit

SN - First scan of new object, starting with star

K - Sky or dark scan - single slit

KN - First scan of new object, starting with sky

D - Double slit data

DN - First scan of new object, double slit.

Any other code will cause the scan to be ignored.

When the function is executed, it first requests a reduced data scan # on which to begin storing the output scans (if switch 3,3, output to IBM tape is up, then this step is skipped since output to IBM tape always goes to the end of the tape). Then the program will ask for a starting and ending raw data scan no. (if switch 3,2, input from IBM tape is up, then an IBM file no. will also be requested).

When the end of the raw data scan range is reached, another will be requested. Observations of a single object may span many Dectapes. When all the data has been reduced, enter ESC for the scan range to force the last object to be reduced.

Switches 4,7 and 4,8 function as described under the New Reduce and Store Scan command (#32).

34. Measure EQW

This program is used to measure the equivalent widths of absorption lines in reduced data. The user marks a left and right continuum point and the computer integrates the area under a linear interpolation between these points. Switch 2,3 controls the vertical scale. Higher than normal vertical scales can be used to measure very weak absorption lines. At all scales, the peak channel is near 800 on the CRT. At higher scales the zero level is off the bottom of the screen.

If switch 3,12 is used instead of 3,11, the data will be replotted on the CRT, perhaps with a new vertical scale. If switch 3,10 is used, a new reduced scan will be requested.

35. Publication Calcomp Plotting

This program is intended for the preparation of Calcomp plots for publication; it will plot reduced scans in four different modes. These are Normal, Dots, Large Dots, and Interpolated. The Normal plot is similar to plots produced by other plotting programs, but no vertical lines are drawn at the beginning and end of the plot. The X CRT function dot mode is used to produce a dots plot. In this mode the pen is raised and lowered at each point. The Large ots mode draws larger dots at each data point. Because of the size of the dots, at least 5 and preferably 10 steps per point should be used. The Interpolated mode draws a line plot but connects the points with straight line segments. This is done by linearly interpolating a Y value for each horizontal step of the Calcomp plotter. It takes 10 to 15 seconds for this interpolation before the plot can begin.

36. Measure Radial Velocity

This program can be used to measure radial velocities on reduced scans. The program uses a first moment algorithim to measure the line positions. Normally, absorption lines are measured, but with switch 3,7 set emission lines can also be measured. The reduced scan indicated by the user is displayed on the CRT and the user is asked to mark the line at the threshold. Using the X position of the cursor as an approximate position and the Y position as the threshold, the program takes the first moment of the line below this threshold (or above, if 3,7 is set). The first moment position is marked with a vertical line and the wavelength will be requested. If the line has been poorly measured, use ESC to remeasure the line. After the wavelength is entered, more lines can be measured by the same procedure. When all lines have been measured, hit switch 3,10. The program will then produce a table of individual line velocities, and allow the user to edit out or re-identify lines. When this is finished, the program will insert the average velocity into the ID area and store the scan back onto the tape. Unit 6 must be write enabled for this. The data is not shifted to remove the velocity. This can be done using the Reduced Data Add, Sub, etc. command (#24). Note: If the earth's velocity was shifted out when the data was reduced, then the measured velocity will be heliocentric.