UNIVERSITY OF CALIFORNIA

LICK OBSERVATORY TECHNICAL REPORTS

No. 14

THE SCANNER DATA TAKING PROGRAMS

USER'S MANUAL

J. A. BALDWIN AND L. B. ROBINSON

Santa Cruz, California
December 1975
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Words of Wisdom:

"To err is human,

but to really foul things up requires a computer."

-Anon.

However:

"Garbage in, garbage out."

-Even More Anon.

I. INTRODUCTION

A. General Features

The Lick Observatory image tube scanner is controlled by the PDP 8/I computer located in the readout room in the 120-inch telescope building. The Scanner Data Taking System (SDTS) consists of a group of related computer programs used to control operation of the scanner. These programs provide for the initial setup of the scanner at the start of the observing run, data taking and data storage on DECtape during the night, on-line data analysis, diagnostic testing of the equipment, and some aids to telescope use such as on-line precession calculations, and telescope offset control.

The SDTS is contained on a single DECtape, which should be mounted on tape drive Unit 8. The system should be "bootstrapped" (basic information about the bootstrap procedure and general use of the computer can be found in Lick Observatory Technical Report No. 1). The SDTS is controlled principally from the programmable switch panel attached to the computer. The SDTS is split up into several basic "programs" which do not generally intercommunicate; these programs are started by setting switch 1, 1 (the upper left switch on the panel) to the desired program, then typing CTRL-C (i.e., type "C" while holding down the CTRL button on the teletypewriter), then typing "G " or "GO". The computer will read the position of switch 1, 1, spin the tape for a while, and away you go . . .

The programs presently available on switch 1, 1 are:

Switch Position	Program		See Pages
0	---		
1	Memory Test		13
2	Initialize	Data Taking	3
3	Continue	Data Taking	4
4	Set Sweeps		10
5	---		
6	---		
7	Peak Finders		13

If either the "Initialize Data Taking" or "Continue Data Taking" programs are selected, the computer will then respond to any of the other switches on the panel. These switches allow data to be taken, displayed, added, sky subtracted, divided by calibration spectrum, etc.

B. Hardware

The Image Tube Scanner (ITS) is a chain of three image tubes followed by an image dissector (see Robinson, L. B. and Wampler, E. J. 1972, Pub. A.S.P. 84, 161). The output phosphors on the image tubes provide a short-term storage capacity for events detected by the scanner, so that the image dissector is able to scan a 4096 channel raster without missing events. The raster pattern is normally two approximately linear segments of 2048 channels each, corresponding to spectra seen through two entrance apertures. The image dissector counts for about 1 μsec in each channel, so that a full 4096-channel cycle requires about 4.4 msec (including flyback time).

The two dimensional sweep pattern of the image-dissector is controlled by a combination of a high-stability, hard-wired ramp generator for the x-coordinate and a programmable circulating memory for the y-coordinate. The y sweep pattern and the center position of each of the two x sweeps must be loaded by the computer. The sweep control hardware is mounted on the telescope.

The scanner's counting and data storage are handled by the "scanner memory" box in the control room. Incoming counts are added into a 4096 channel, 24-bit circulating memory which is clocked in synchronization with the image-dissector sweep. The contents of the memory are continuously displayed on an oscilloscope. Manual controls or computer control allow this memory to be enabled, disabled, or cleared. The computer can be used to enable the memory for a preset number of sweep cycles, after which the scanner will automatically stop counting and will raise a flag to inform the computer that it is finished (this is the normal means of taking data). The computer will then read the memory and transfer its contents eventually to DECtape.

The hardware used by the SDTS programs includes the PDP 8/I computer, teletypewriter, 32 K computer disc, switch panel, CRT display scope, joystick, Calcomp plotter, two DECtape drives, 9-track tape drive, scanner memory, scanner sweep control and associated multiplexer, the spectrograph control box (the one attached to the spectrograph), and the telescope position display and position control and associated multiplexer. All of these peripheral devices must be up and running if all options on the SDTS tape are to work properly. Chapter V ("Troubleshooting") describes some of the symptoms of failures in any of these devices. The minimum hardware required for setting up the scanner and for taking data are the computer, teletypewriter, switch panel, one DECtape drive, scanner memory, and the scanner sweep control and associated multiplexer. A special

"No-Disc" SDTS tape is available for use if the computer disc fails.

It is almost impossible to damage the computer or the scanner by operator errors or hardware failure. However, some precautions can be taken to make the risk even less.

1. Always set sweeps as soon as the sweep box power comes on, and again after a power failure. This is to avoid possible heating up of sweep circuitry.

2. The Program Tape on DECtape transport 8 is used to store scanner sweep settings, calibration, etc. When no such writing is to take place, the write control switch should be left on Write Lock. If you forget to set Write Enable, the program will type Tape? and keep on trying until write Enable is set. It is advisable to remove tapes before shutting off the computer.

3. The two high voltage power supplies should not be set above 2400 and 30,000 volts respectively.

4. The memory oscilloscope screen can be burned by overexposure. Do not turn up the brightness unnecessarily. Turn off the oscilloscopes when they are not to be used for several hours.

II. DATA TAKING PROGRAMS

The heart of the Scanner Data Taking System is in the data taking programs, which can be entered by calling either the INITIALIZE DATA TAKING or CONTINUE DATA TAKING programs. Most of the functions marked on the switch labels (i.e. data reduction, display, processing, telescope offset, etc.) will work only when the data taking programs are in use.

These programs spend most of their time in a loop testing to see if any of the buttons or toggles on the switch panel are being pressed. Once a button or toggle is recognized, the appropriate function is executed. The prime function of the data taking programs is to supervise data taking and, at the end of each scan, to transfer data from the scanner memory to DECtape. Scans are started by pressing the green "START" button (3, 8). At the end of a pre-set integration time, scans are stored on tape as scan numbers 0-17, where the scan number refers to the position on the DECtape. The programs automatically reset the current scan number to 0 and request a tape change after scan 17 has been stored on tape.

A. INITIALIZE DATA TAKING

This program is used to initialize the variables used by the data taking programs. It is normally called only at the beginning of the night. The

teletype will ask the following questions, which must be answered before the program will proceed. Most responses must be followed by pressing the space bar or the "Return" key.

(1) TYPE FIRST SCAN NO.:
(normally 0)

(2) WANT LOG I.D. ON DATA TAPES? (Y/N): (normally Y for YES, to get identifying information as described in Chapter VII.)

(3) L/R RESPONSE RATIO (USUALLY = 1): (this should be the relative sensitivity of the two entrance apertures. It can be determined by scanning the twilight sky and entering the ratio of the total counts in the left and right slits.)

(4) COUNT IN PROGRESS (Y/N): (answer Y only if a scan has been started by the green START switch (3, 8) and has not yet been terminated and stored on tape.)

B. CONTINUE DATA TAKING

This program should normally be used when returning to the data taking mode after using some other program. It is an alternate way of entering the data taking programs. The program will usually know what the current scan number is and whether the count is in progress by referring to special codes on the disk, but if the "INITIALIZE DATA TAKING" program has not been previously used, or (for most changes) if the disk codes have been changed, the INITIALIZE DATA TAKING PROGRAM will be automatically called. In either case, the computer will return to the normal data taking mode and type either "SCAN--READY" or "SCAN--IN PROGRESS".

C. Functions Available in the Data Taking Mode

These functions are available when either the INITIALIZE DATA TAKING or CONTINUE DATA TAKING programs have been called. They are controlled by the various toggle switches and push buttons, with parameters preset on the rotary and lever switches.

(1) START (3, 8) - start counting, and stop automatically at the end of the counting time set on switch 1, 7.

(2) RESET (3, 9) - stop counting, do not store data on tape, do not increment current scan number.

(3) STOP (3, 10) - stop counting, store data on tape, increment current scan number.

(4) SPECIAL FUNCTIONS (3, 2) - (calls function selected by switch 1, 4). Several functions allow data in 3 buffer areas to be manipulated.

(a) ERASE - erase the sum buffer. (The "sum" buffer holds a 4096 channel scan with 2048 "star + sky" channels followed by 2048 "sky" channels.

(b) SUBTRACT - subtract "last-run buffer" from sum buffer. Teletype asks "L or R?"; if L is specified, the left slit data is subtracted from the "star + sky" part of the sum buffer and right slit data from the "sky" part of the sum buffer. (Vice versa if "R" is typed.)

(c) ADD LEFT - left slit data of last-run buffer is added to "star + sky" part of sum buffer; right slit data is added to "sky" part of sum buffer.

(d) ADD RIGHT - right slit data is added to "star + sky" part of sum buffer; left slit data is added to "sky" part of sum buffer.

(e) Blank Position

(f) SCRUNCH - transform contents of sum buffer to a linear wavelength scale, using a wavelength calibration previously determined in the λ I.D. SETUP function. The result is put in the last run buffer. This operation takes about 2 minutes, and leaves the sum buffer unchanged.

(g) SMOOTHING - applies smoothing function to contents of "sum" buffer, puts results in "last-run" buffer. Smoothing is by convolving either a Gaussian (of any width, in channels) or the Fourier transform of a step function (to cut off high frequency noise). This operation takes about 1 minute, and leaves the sum buffer unchanged.

(h) PROGRAMMED SEQUENCE - for combining data already stored on tape. The CRT will display a set of codes for various options (add to sum buffer, add to calibration buffer, etc.). Option codes, along with scan numbers as required, are typed in, corrections may be made as needed, and then the program is executed.

(5) COMMENTS (3, 3) - allows comments up to 64 characters in length to be stored with the scans on tape; you will be asked to type in the number of the scan to which you wish to add the comment, then you will be asked to enter a comment, ending with the "RETURN" key.

(6) PAUSE (3, 4) - setting this switch will cause counting to be temporarily discontinued, and the scanner clock will be stopped. When the switch is returned to the OFF position, the count will continue.

(7) PLOT (3, 5) - Calcomp plot of data from any of the disk buffers. Before pressing the plot switch, the desired parameters are set up using the levers on the switch panel (for scale, source buffer, slit, points averaged, and plotter control) and the rotary switch for offset. Full scale on the plotter is the product (Full Scale)*(Full Scale Multiplier) *1024 counts. The scale may be tested by using switch (3, 7) to display the same data at the same scale on the CRT.

(8) RECALL A RUN (3, 6) - recalls a scan from tape unit 7 and stores it in the "last-run" buffer. The scan is automatically displayed on the CRT - the scale and offset switches should be set before pressing this switch.

(9) DISPLAY (3, 7) - CRT display of data from any of the disk buffers. Before pressing the display switch, the desired parameters are set up using the levers on the switch panel (for scale, source buffer, slit, and number of points averaged) and the rotary switch for offset. Full scale on the CRT is the product (Full Scale)*(Full Scale Multiplier) *1024 counts. This can also be used to display the current content of the scanner memory on the memory scope, even while counting.

(10) MORE GOODIES (4, 7) - (calls function selected by switch 4, 1)

(a) SKY LINE MONITOR - finds and prints positions of emission peaks in both left and right slits of Last Run Buffer. The approximate positions of these peaks must be entered in advance with the SKY LINE MONITOR SETUP function (see §11.a)

(b) LAMBDA I.D. - cursor is displayed on CRT. Use the joystick and button 3, 11 to mark the position of a feature of interest appearing in the CRT display. The channel number and wavelength of the cursor position will be typed out. The wavelength is calculated using calibrations previously determined in the "λI.D. SETUP" program (§11.b)

(c) ROCKER - rocks spectrograph grating back and forth between two specified limits. See Chapter V.

(d) TAPE I/O - reads or writes DECtape, to or from one of the disk buffers (as selected by switch [2, 9]). This could be used, for

example, to save the contents of the sum buffer, or the calibration curves, on the program tape.

(e) POLARIMETRY - complete on-line polarization analysis (all four Stokes' parameters as a function of wavelength) for data taken with the Nordsieck polarimeter. See Chapter VIII for details.

(f) LOAD SWEEPS - loads scanner sweep pattern from tape, after asking for sweep number. The sweep patterns must have been preloaded on tape, using the "SET SWEEPS" program. This allows for rapidly resetting or changing sweeps. See Chapter III.

(g) CHANGE SPEC SETUP - reads a set of desired spectrograph settings from tape and then changes the spectrograph settings to match. This function will also load new sweeps, load a quartz lamp spectrum from tape unit 8 into the calibration buffer, and set up the proper wavelength calibrations, if desired. You will be asked for a "SETUP NUMBER," referring to a set of desired settings previously stored on the SDTS tape using the STORE SPEC SETUP function described below.

NOTE: If the remote spectrograph control panel in the readout room is connected to the system, the dark slide and corrector slide positions cannot be changed under computer control.

(h) STORE SPEC SETUP - used for entering and listing the spectrograph "setups" used by the "CHANGE SPEC SETUP" function described above. These setups are little programs for changing the spectrograph settings under computer control, and 35 of them can be stored in a special area on the SDTS tape. The teletypewriter will first ask "LIST SETUP NO (-1 TO END, Ø = CURRENT READINGS, 1-35 FROM TAPE)". Enter -1 to move on to the next step, enter Ø to have the present settings of the spectrograph read and printed out, or enter the identifying number of a setup (1-35) which you wish to have read from tape and listed.

The next step asks "EDIT SETUP NO (-1 TO END)". Enter -1 to move on to the final step, or a setup number (1-35) to enter new values to be stored on tape. If you choose to edit a setup, you will be asked to enter a setting for each parameter on the

spectrograph, as well as sweep, quartz calibration and lambda calibration numbers. The sweeps must have been previously loaded on tape using the "SET SWEEPS" program (Chapter III), the quartz lamp calibration scans must have been previously loaded on the SDTS tape using the SPECIAL FUNCTIONS and TAPE I/O routines (see Chapter V for the recommended procedure), and the lambda calibration must have been stored on tape using the "λ I.D. SETUP" function. Acceptable entries while editing setups are: any allowable setting for the device in question, or -1 to cause the setting to be left unchanged when the CHANGE SPEC SETUP function is used, or ALT MODE or ESCAPE key to leave unchanged whatever setting was previously stored on tape.

The final step is a choice of whether or not to store the altered spec setups on tape.

(11) STILL MORE STUFF (4, 8) - (calls function selected by switch 4, 4)

(a) SKY LINE MONITOR SETUP - for entering the expected positions of night sky emission lines so that the SKY LINE MONITOR function can check their positions as a test for wavelength stability. Display the sky spectrum on the CRT (using the DISPLAY switch), then call this function and use the joystick and switch 3, 11 to mark the positions of up to 25 sky lines. End by marking the same position twice.

(b) λ I.D. SETUP - loads wavelength calibrations for use with the λ I.D. or SCRUNCH functions. Calibrations previously stored on the SDTS tape (and numbered Ø-14) may be recalled, or a calibration stored on a Scanner Data Reduction System tape (mounted on unit 7) may be recalled and stored on the SDTS tape, or a new calibration can be determined. In the later case, you will be asked to display a comparison lamp spectrum and mark at least five emission lines (using the joystick and button 3, 11) and give their wavelengths. A cubic fit for λ=f (channel number) is made and the residuals are listed.

(c) LOG EDIT - will read any scan from tape and ask you to enter (via the teletype) all of the log I.D. information (dwell, telescope position, object name, P.S.T., spectrograph setup). Edited scan is then saved back onto tape unit 7. Use "ALT MODE" or "ESCAPE" keys for entries you wish to leave unchanged. IMPORTANT: if the

(c) Continued

question "SCAN:" is answered by the ALT MODE or ESCAPE keys, you can then change the slit code for the scan currently in progress.

(d) LOG LIST - will list log I.D. information for up to 18 scans (from tape on unit 7). The stuff you have to type in yourself is underlined on the sample - TAPE NO. and DATE are strictly for I.D.; you can enter anything.

USER RESPONSES ARE UNDERLINED.

LOG LIST. RAW DATA SCANS---1ST:<u>0</u> LAST:<u>16</u> ← FROM DATA TAPE (UNIT 7)

TAPE NO:<u>3</u> DATE:<u>16/17 DEC 1974</u> ← DUMMY ENTRIES.

SCAN	DWELL	H.A.	SLIT	SETUP	COM	NAME	R.A.	DEC	PST
0	480	2 53	R	295		4C25.05	1 23 32	25 50.4	01 40
1	480	3 2	L	295					
2	480	3 11	R	295					
3	240	3 21	L	295					
4	.0	1 52	N	295					
5	240	0 58	L	295		3359+161	3 59 24	16 12.0	03 22
6	480	1 3	R	295					
7	480	1 12	L	295					
8	480	1 23	R	295					
9	240	1 32	L	295					
10	240	2 32	L	295		0313+167	3 13 5	16 50.7	0 16
11	480	2 37	R	295					
12	240	2 46	L	295					
13	240	- 2-22	L	295		0832+123	8 32 1	12 16.5	3 36
14	240	- 2-17	R	295					
15	240	- 1-40	L	295		0833+115	8 30 5	11 23.1	1 8
16	240	- 1-42	R	295	X				

SETUP	TILT	SELECT	L.FILT	H.FILT	CORR	COLL	DECKER	SLIT
295	13342	400	26	34	0	50	355	70
295	14032	1	26	34	0	50	355	70

COMMENTS

16-WE'RE BEING CLOSED BY THE #$%&'!"#$% HUMIDITY!

(e) TELESCOPE OFFSET - computer will move the telescope by a precisely determined amount first in R.A., then in Declination. Enter Δ DEC (in minutes, then seconds of arc), Δ R.A. (in minutes, then seconds of arc), or Δ R.A. (in minutes, then seconds of time). Enter zeros for either the time or arc units (i.e. the units you are not using) for R.A. There is no limit to the R.A. move; maximum DEC move is $\pm 1^{o}50'$ from the center of the tangent arm travel. Inform the night assistant before making long offsets, so that he can safeguard the T.V. camera.

(f) SKY OFFSET - load (sky-star) offsets for automatic slit changer [toggle (4,11)]. Uses same entry procedure as (e).

(12) CHANGE COUNTING TIME (4, 9) - teletype asks for new counting time for a scan in progress. This should be the desired total counting time, in minutes; if this time has already been exceeded, the scan will be terminated as if the 3, 10 STOP button had been pushed. Or enter -1 to escape.

(13) ENABLE X-Y STAGE (4, 10) - use with (4, 11) to cause x-y stage to automatically compensate for slit changing, when offset guiding in diagonal mirror position 3.

(14) ENABLE AUTO SLIT CHANGER (4, 11) - at the end of a scan, the computer will move the telescope between slits in response to L, LN, R or RN slit codes, or for B, BN, S, or SN codes it will apply a (sky-star) offset entered via the SKY OFFSET function on the STILL MORE STUFF switch. [See Chapter VI]

(15) PRECESSION (4, 12) - for precessing coordinates from any epoch to any other epoch. The teletypewriter will ask for the old epoch, the right ascension (hours, minutes, seconds), declination (degrees, minutes), and finally the new epoch. The precessed position will then be printed. If switch 4, 12 is left up, the program will loop back and do another precession calculation after first checking that a scan has not ended and that the START, STOP or RESET buttons are not being pushed.

III. THE SET SWEEPS PROGRAM

This program is used to locate the spectra on the image tube face, and to set up the y-sweep pattern so that the image dissector "sees" the spectra. The sweeps must be properly set before any data can be collected.

The spectra can be located either manually or automatically. To do it manually, ask for the tube to be mapped (see sample teletype listing page 12), using a sensitivity

scale of 10 to 20 "counts per dot". Before starting this map, be sure that the spectrograph slit is set to 50-100, that the one second decker is in use, that the dark slides are open, that the grating tilt is reasonable to produce a spectrum, and that the quartz-iodine continuum lamp is turned on. A 2.5 mag neutral density filter is recommended. The computer will make a raster scan of the image tube face (from the bottom up) and display the results on the CRT. The two spectra should appear as bright, approximately horizontal swathes of light on the screen. If for some reason you want to start mapping from the bottom of the screen again, push (and hold down for 5 seconds) button (3, 12) on the teletype near the joystick. Once the two spectra are clearly discernible, push (and hold down for 5 seconds) button (3, 11). [Note that only the middle portion of the face is displayed. The Y scale is amplified by 4 relative to X.]

The teletype now asks: SWEEP # (-1 = NO CHNG, Ø = JOYSTICK, 1-8 FROM TAPE): If you are manually setting sweeps, ask for the joystick (enter Ø) and use the joystick and button (3, 11) to mark points along the two spectra. The joystick will move a cursor on the CRT screen, and pushing the button will cause the position of the cursor to be stored. Mark 5 to 10 points in the top spectrum, moving from left to right, then mark the bottom spectrum. The sweeps will be linearly interpolated between the points marked, and will be displayed on the CRT for your verification.

If you wish to set sweeps automatically, enter -2 for the SWEEP # after first turning on the quartz lamp. The computer will make vertical scans of the tube face at six different x-positions. The spectra should show up on the "live-display" oscilloscope as a series of double bumps. The x and y positions of the two spectra will be printed for each step. You will be asked if you wish to repeat any step. Enter -1 if not, or enter the step number. If the y positions are obviously wrong for a few of the x positions, the grating tilt is wrong and light is not falling into some part of the spectrum, so change the grating tilt and repeat the step. Recommended grating tilts are:

Grating	Tilt
1, 2	22000 (red tube) or 20000 (blue tube)
3	30000
4	40000
5, 6	15400

Other acceptable entries for SWEEP # are Ø, to leave the sweeps unchanged and move on to the next stage of the program, or a sweep number 1 through 8, to read that sweep from tape and load it into the y-sweep memory.

The teletype next asks for a LEFT SLIT CHANNEL OFFSET, which is a small x-offset applied to one of the sweeps to get better wavelength correspondence between the left and right slit data. Typical numbers are in the range ± 20, and can be determined empirically by trying to make emission lines in the left and right slit comparison spectra occur at the same channel number. This offset is stored on tape with the sweep; if you have just read in a sweep and wish to leave the offset unchanged, press the ALT MODE or ESCAPE key.

The next question is CURVES OK?; if not, the program loops back and asks for a new SWEEP #. If yes, you are asked SAVE AS SWEEP NO:; enter 1-8, or -1 to not save the sweeps.

Sample teletype output (user responses are underlined):

MANUAL SWEEP SETTING:

```
SET SWEEPS
MAP TUBE? <Y/N>:Y                                   ← map tube, sensitivity scale = 12.

COUNTS PER DOT:12
SWEEP # (-1=NO CHNG, 0=JOYSTICK, 1-8=FROM TAPE):0   ← mark position of spectrum
                                                      with joystick.
TRACK TOP SCAN

LEFT SLIT CHANNEL OFFSET:00        OFFSET=   00
CURVES OK? <Y/N>:Y

SAVE AS SWEEP NO:1                                  ← save on tape & as sweep 1.
ALL SET
```

AUTOMATIC SWEEP SETTING

```
SET SWEEPS                                          ← No need to map tube.
MAP TUBE? <Y/N>:N
SWEEP # (-1=NO CHNG, 0=JOYSTICK, 1-8=FROM TAPE):-2  ← -2 for Auto Sweep Setter.

START LAMP: USE 1 SEC DECKER

                                  sweep 1
                                  sweep 2
STEP    X     Y1     Y2
   0   170  1934   1583
   1   514  1935   1697
   2   858  1927   1693          ← Peruse this table for
   3  1194  1919   1591            wild points in Y1 or Y2
   4  1534  1919   1587
   5  1874  1923   1587

REPEAT STEP NO:-1   ← no wild points — all O.K.
LEFT SLIT CHANNEL OFFSET:00        OFFSET=   00
CURVES OK? <Y/N>:Y
SAVE AS SWEEP NO:1                                  ← save on tape & as sweep 1.
ALL SET
```

IV. TEST PROGRAMS

A. MEMORY TEST

This should be used when the scanner is first turned on after an extended rest. It presets control registers in the scanner memory hardware, and then loads a sequence of numbers into the memory, and reads them back, to give an elementary check that the scanner memory and computer interface are functioning. Bad channel numbers, along with the good and bad data for such channels, will be printed on the teletype. If any errors occur, call for help.

Since this test will erase both data and sweep positions in the scanner, it first requests permission to proceed. Answer "YES" or "NO".

B. FIND PEAKS

You will be asked to select one of two options:

(1) FIND ALL PEAKS - a useful test of scanner stability can be done by repeatedly recording a line spectrum (using the neon lamp), then printing out channel number of line positions for repeated scans.

This program can use data previously stored on DECtape, or it can collect data from the scanner tube directly. It first asks "TAPE OR TUBE". If you say "TUBE", it will repeatedly run the scanner for the time set on switch #1,7, print out the peak centers, wait for 15 minutes or so and repeat. The neon lamp would be left on continuously. Since the scanner phosphor has a long memory, this procedure would not be used if observations were planned the same evening.

If you answer the question by typing "TAPE", the program expects data on DECtape #7. It asks for a series of scan numbers and slit ("L" or "R"). Type in the list, and terminate with -1.

E.g.,

```
:3    :L
:4    :L
:7    :L
:-1
```

The peaks found in the first scan are printed out, with "?" printed for those where the highest channel does not correspond to within one channel of the measured center. On successive scans, the program prints the error for each peak position compared with the position found in the first scan, provided the difference is less than 3 channels. Peak positions are compared with those in the first scan, and the error is printed for any peak falling within 3 channels

of its original position. A weighted average error is also printed.

(2) STABILITY CHECK - This program will find the positions of prespecified lines in a sequence of scans, so that shifts in the line positions can be detected. Option 1 should be used to find the positions of several strong peaks spread throughout the spectrum. The stability check program will ask for the channel numbers of these peaks, and then ask if the scans are already stored on tape or if the program should repeatedly run the scanner for the counting time set on switch (1, 7). If you ask the computer to run the scanner, just turn on the neon lamp and let it run for as long as desired. If the scans are already on tape, enter the scan numbers. As each scan is read in from tape or tube, the positions of the peaks will be listed.

V. SCANNER SETUP PROCEDURE (OBSERVERS DUTIES)

(1) Turn on the computer, teletype, CRT, "live display oscilloscope, and anything else that looks likely. Put the diagonal mirror in position 2. Open the manual and remotely controlled dark slides.

(2) Set sweeps for each grating. Use a 2.5 mag neutral density filter in front of the quartz lamp. Do not expose the scanner to more light than necessary.

(3) Focus the system for any one grating. Set the spectrograph slit to 40. Vary the dissector voltage by $\pm$ 50 volts or so (controlled by the thumbwheels on the power supply mounted beneath the scanner memory and CRT) to find the best electronic focus and then vary the collimator focus until the best resolution is found. A good resolution test is to look at the dip between two partly blended emission lines in the comparison spectrum. The 2.5 mag neutral density filter must be removed to see the emission lines clearly. The focus will vary across the spectrum, so try for a best compromise.

(4) Determine the "LEFT SLIT CHANNEL OFFSET" required to lineup emission lines in the center of the left and right slit spectra. Use the SET SWEEPS program:

NB - Press space bar after each response

```
SET SWEEPS
MAP TUBE (Y/N): N
SWEEP NO. (-1 = NO CHANGE, Ø = JOYSTICK, 1-8 FROM TAPE): 1
                                   (recall sweep set in step (2)
LEFT SLIT CHANNEL OFFSET:  18 OFFSET = 18
                                   (try an offset)
CURVES OK? (Y/N): N                (wrong offset)
┌→SWEEP NO. (-1 = NO CHANGE, Ø = JOYSTICK, 1-8 FROM TAPE): -1
|                                  (Keep same sweep)
|  LEFT SLIT CHANNEL OFFSET:  17 OFFSET = 17
|  SWEEPS OK? (Y/N) N:
└──(loop until a good offset is found)
```

SWEEPS OK? (Y/N) Y

SAVE AS SWEEP NO. 1 ← re-save on tape

If desired, sweeps already saved on tape can be called, a new offset typed in and the sweep re-written on the tape with the corrected offset.

(5) Determine the grating tilts and filter combinations to be used during the night. Note that the correspondence between central wavelength and grating tilt reading can change from month to month, so you should check your settings with the comparison lamps.

(6) Call the INITIALIZE DATA TAKING program, then change switch (1, 1) to CONTINUE DATA TAKING.

Make calibration scans of the "quartz" continuum lamp. Do this for each grating. These "quartz" scans will be divided into the data to normalize out small scale irregularities in the scanner response. To get a smooth continuum spectrum extending across the whole wavelength range of the scanner, either take scans at several different grating tilts and add them together in step (7), or use the "ROCKER" function on the "MORE GOODIES" switch. The ROCKER slowly rocks the grating back and forth between two limits, smearing the spectrum across the image tube face. The number of counts in the center channel of the right slit spectrum will appear on the LED display on the switch panel, and is updated at the end of each rocking cycle.

To use the ROCKER function:

(a) Start a 32 minute scan.

(b) Type in label information.

(c) Use the MORE GOODIES toggle switch to call the ROCKER function.

(d) Enter minimum and maximum tilts:

Grating	Min	Max
1, 2	18500	28500
3	20000	40000 (no Cu SO_4 filter)
5, 6	12000	19200

(e) Turn on quartz lamp.

(f) Wait until LEDs display desired number of counts (~100,000 for 1% accuracy since we get about 10 counts per photoelectron.)

(g) Set the PAUSE switch up and wait until the lights above the PAUSE switch start to blink.

(h) Turn off the PAUSE switch and push the (3, 10) STOP button to save the spectrum on tape.

(7) Process the quartz lamp scans and store them on the program tape (unit 8). Call the PROGRAMMED SEQUENCE function on the SPECIAL FUNCTIONS switch, and use the following sequence:

1:CX	(clear the calibration buffer)
2:CQ 3:1	(add quartz scans from scans
4:CQ 5:2	1, 2 etc. on data tape)
6:CF	(normalize calibration buffer - THIS IS A VITAL STEP)
7:S 8:16 9:4	(save calibration buffer (coded 16 on disc) on tape 8 as scan 4, for recall later during the night)
.	
.	
.	
CX	
CQ	repeat for the other two gratings, saving as scans 5 and 6 (or use any scan number >3 on program tape).
.	
.	
CF	
S	
.	
.	
20:Q	(end of sequence)
21:B AT STEP NO. 1	(begin execution at step 1)

(8) Take scans of the emission line comparison lamps shortly before you start observing. 30-60 second scans are usually sufficient. Long exposure to bright sources will increase the tube background for many minutes, so keep lamp scans as short as possible.

(9) If desired, get wavelength calibrations from the scans taken in step (8) and store them on the program tape. Use the LAMBDA ID SETUP option on the STILL MORE STUFF switch. These calibrations are not necessary, but they will allow you to measure wavelengths from the CRT display and to use the SCRUNCH function during the night.

(10) Use the STORE SPEC SETUP program on the MORE GOODIES switch if you plan to use the computer to change spectrograph setups during the night.

VI. AUTOMATIC SLIT CHANGING

If switch (4, 11) "ENABLE AUTO SLIT CHANGER" is left up at the end of a scan, the computer will read the slit code for that scan and automatically move the telescope to the other slit. It will recognize codes R or RN for "right slit" and L or LN for "left slit". The declination and tub position angle are taken into account. If you are looking at extended objects, enter an offset for (sky-star) via the SKY OFFSET function on the STILL MORE STUFF switch. The computer will recognize codes B or BN for "object in both slits" and move the telescope to the sky position. Codes S or SN are recognized as "sky in both slits" and the telescope is moved back to the object position. Inform the night assistant if you are making long offsets to sky, so that he can close the TV camera shutter during the move. The (sky-star) offset is automatically set to zero when you call the INITIALIZE DATA TAKING program.

If switch (4, 10) "ENABLE X-Y STAGE" and switch (4, 11) "ENABLE AUTO SLIT CHANGER" are both up and codes L, LN, R or RN are used, the x-y stage (i.e. the reticle) will be moved to compensate for the slit change. This feature is of use if you are guiding on an offset star seen on the diagonal mirror in position 3, and not on the slit jaws.

VII. LOG I.D. INFORMATION STORED ON SCANS

Labels containing identifying information will be stored with each scan if the computer is told to do so during the INITIALIZE DATA TAKING sequence. The information stored includes the star name, dwell time, spectrograph settings, telescope coordinates, a slit code, the PST, and alphanumeric comments. When each scan is started, the teletype requests a slit code; standard codes used by the Santa Cruz reduction programs are:

L = star in left slit

R = star in right slit

B = extended object filling both slits

S = sky in both slits

Q = quartz lamp in both slits (no atmospheric extinction correction required)

Appending an N to any of these codes (i.e. LN, RN ...) will cause the teletype to request an object name and the PST. The object name can be up to twelve characters in length and must be terminated by the RETURN key. The PST is entered in hours

and minutes. Both of these entries are then carried unchanged until the next use of LN, RN, etc. All other I.D. information is obtained automatically, and updated at the beginning of each scan.

VIII. USE OF PDP-8 SCANNER POLARIMETRY PROGRAMS

BY K. NORDSIECK, FEBRUARY, 1974

(1) GENERAL DESCRIPTION

I have written FOCAL programs for the Scanner Data Reduction System (SDRS) and Data Taking System (SDTS) for rough reductions of data taken with the Polarization Analyzer ("PAN") in the lower filter wheel of the Cassegrain Spectrograph-Scanner. These programs take scans, either wavelength-calibrated or not, and put them on a scale in which the filter-imposed fringes have constant separation across the spectrum, and then compute the Fourier coefficients corresponding to the Stokes parameters Q, U, and V in a number of wavelength bins. A calibration table must first be computed for a particular grating setting, using a scan of the quartz lamp taken through PAN. This will show about 60 percent polarization in the Q sense because of a 90^{o} reflection off the diagonal mirror. With the help of a CRT display of this spectrum and a sky or neon spectrum, you identify the two leftmost and the rightmost fringe maxima from a table shown on the CRT, using the joystick marker (the table contains wavelengths of every third fringe - use these only). The program then finds the fringes in between, as well as some intermediate minima, and displays the positions by arrows at the bottom of the screen. A table related to these positions is stored. On subsequent entries to the program, the scan to be analyzed is "scrunched" using this table, Fourier analyzed, and a table is printed out which contains the central wavelength of each wavelength bin, the <u>percent</u> signal for Q, U, and V in each bin, the percent error in Q evaluated from non-signal Fourier coefficients (the error is 1.4 times larger for U and V), the percent polarization $P_{linear} = (Q^2+U^2)^{1/2}$, and the position angle P.A. = 0.5 arctan (U/Q). The first row in the table contains the averages across the spectrum, where the wavelength bins are weighted inversely as the error squared.

(2) IMPORTANT POINTERS

(a) Scans of an object taken through PAN should always be divided by straight scans of the same object taken at the same grating setting, before using the calibration or reduction phases of the programs. This removes the effects of irregularities in the image tube, spectral lines, and trends in the spectrum which leak into the fringe frequencies.

(b) Since 100 percent polarization does not give a full 100 percent fringe signal, because of various effects in the image tubes and dissector, a calibration scan of a star taken through the polaroid (POL) in the upper filter wheel and PAN is needed to compute (by hand) the final percent Q, U, and V.

(c) The position angle calculated by the programs is arbitrary, and must be calibrated using known linearly polarized stars and/or the Cassegrain tub rotation readout.

(d) The "cross-talk" between the Q, U, and V signals depends on the quality of the fringe position calibration obtained with Quartz+PAN. This is important if, for instance, you are looking for a circular polarization signal (V) in the presence of a large linear polarization signal. The systematic error should then be evaluated using reductions of Quartz + PAN and Star + POL + PAN. With the crude PDP-8 programs, you shouldn't expect better than 10- or 20-to-1 separation (worse near the ends of the spectrum). Reducing the slits separately helps, since the calibrations are slightly different.

(3) DETAILED USE OF PROGRAMS - SDTS

This program uses data from the Sum Buffer, with only the Last Run Buffer being destroyed, so it can be used while taking data. Subroutines are kept in Programs 43, 44, and 45, and the fringe position calibration table is stored in Program 42. The program is reached by calling the POLARIMETRY function on the MORE GOODIES switch.

The program first asks NEW FRINGE CALIB?(Y/N):
If "Y", in the SDTS version, it is expected that a display of (Quartz+PAN)/Quartz is already on the CRT, along with any sky or Neon comparison scans required. The calibration scan (Quartz+PAN)/Quartz must be in the Sum Buffer. The next question DISPLAY READY? (Y/N) allows you to exit with an "N" if you forgot any of these. If you are ready ("Y"), the message DATA FROM SUM BUFFER AND SW(2, 1) allows you to set SW(2, 1) to choose the slit desired: usually "STAR" (left slit), "SKY" (right slit), or "STAR, SKY" (average of the two slits); when ready, hit "ESCAPE". The computer then lists the fringes at the top of the CRT, displays the joystick marker, and rings the bell. With the vertical part of the marker, mark the position of the two left-most well-defined fringe maxima from the table, then repeat for the right-most fringe. The computer then marks the rest of the fringe table positions and mid-interval minima. If this part of the program goes wild, there is probably something wrong with the Sum Buffer data, and you must start

over. The resulting fringe position table is stored on the SDTS tape - remember to set "WRITE ENABLE" for Unit 8. The program then cycles back to the beginning. It is best to check that the calibration is OK by cycling through the reduction section using the (Quartz+PAN)/Quartz scan as data.

If the calibration is already stored, enter "N" for the first question, and the polarization reduction is performed on the contents of the Sum Buffer, with slit options chosen by SW(2, 1). This takes about 15-30 seconds. Control then returns to the main SDTS dispatch program.

Reductions can be done as scans of (Star+PAN) are accumulating in the Sum Buffer during data taking, if scans of the star without the analyzer have been loaded into the Calibration Buffer. It is usually good enough to use a fringe position calibration done the preceeding afternoon at the same grating setting. For quick reductions the next day, it is convenient to use the "PROGRAMMED SEQUENCE" to load the buffers, together with the SDTS Polarization Programs.

IX. TROUBLESHOOTING THE SCANNER

(1) NO COUNTS

HV power supplies on? Discriminator on? Discriminator set too low? (especially for the blue tube). Cables hooked up properly? Scanner memory on? To test everything downstream from the discriminator, set the discriminator to about 800 so that is oscillates, then check that noise counts are being recorded. Run the memory test program.

(2) DARK COUNT ONLY

Light not getting to image tubes? Check that the slit is open, dark slides are open, gratings are set to proper tilt and select and are in fact in the spectrograph, slit is not taped over. Sweeps bad? Try resetting them. Use an oscilloscope to test the waveforms at the testpoints on the sweep control box on the tub (x sweeps should look like sawteeth, y should look sort of like a square wave). Comparison lamps not working? Make sure that R.O. Room-Tub selector switch is set to R.O. Room; check the switches on the comparison lamp selector box on the tub.

(3) NO SPECTRUM WHILE SETTING SWEEPS

See (2) above. Next, bootstrap the current data taking tape and try again. Then, open the decker to 999 (no decker) and try again -- if you see light now, a displacement of the scanner or sweeps may have occurred, implying either a mechanical or an electronic disaster; seek help.

(4) TELETYPE KEEPS TYPING MUX?

One of the three multiplexer units used by the system is not working properly. The problem will almost always be because of a disconnected co-ax cable, or no A.C. power to one of the multiplexer units. If the error message occurs during sweep setting or at the end of a scan, the unit next to the sweep control box (up on the tub) is probably at fault. If the message appears while running the spectrograph control functions, check the control box on the spectrograph. If it occurs at the beginning of a scan, check both the spectrograph control and the unit next to the telescope position display. The "INITIALIZE DATA TAKING" program will test the position display multiplexer if you request tape labels.

(5) COMPUTER HANGS UP

Bootstrap again ... and again. As a last resort, try the emergency "NO-DISC" tape. Once or twice the computer has gotten into a condition that can only be cured by switching power off and on again.

(6) COMPUTER WON'T BOOTSTRAP

Check the disc circuit-breaker, located at the rear of the fifth cabinet from the end, at floor level. Check that the teletype is turned on, and that the computer and the teletype (or Silent 700) are set to run at the same speeds. Be sure to run the program tape several feet onto the takeup reel before trying to bootstrap. Be sure that the computer console switches are correctly set. Check that the expected address (200_8), field 0 comes up on the display lights when LOAD ADDRESS switch is pressed.

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Appendix 1

Scanner Setup Procedure Summary

(See Chapter V, L.O.T.R. No. 14 for details)

(1) Turn on all equipment, check on discriminator setting.

(2) Set sweeps for each grating and store on Tape 8.

(3) Focus --- electronic and mechanical.

(4) Determine LEFT SLIT CHANNEL OFFSET and save with sweeps.

(5) Determine grating tilts and filter combinations to be used during the night.

(6) Use the INITIALIZE DATA TAKING program.

(7) Take and store quartz-iodine lamp calibration scans.

(8) Take comparison scans of emission line lamps.

(9) Store wavelength calibrations for λ I.D. and SCRUNCH (optional)

(10) Store spectrograph setups (optional).