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SCN — A program package for scanning of stellar spectrograms

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The SCN program package for automatical scanning and digital recording of stellar coude-spectrograms in the Rozhen National Astronomical Observatory (NAO) is presented. The SCN is run on the "JOYCE-LOEBL LTD" computer-controlled microdensitometer of the NAO and results in the recording of the spectrograms on a magnetic tape in one of the releases of the FITS format, elaborated for that purpose. The program package is a part of the S software developed in the NAO for coude-spectrograms digital processing.

Key words: software, scanning, microdensitometer, spectrogram.

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1. Introduction

The investigation of high-dispersion stellar spectrograms requires the detailed extraction of the recorded information with as high as possible precision. On the other hand, the computer-controlled microdensitometers make possible the automatical scanning and digital recording of photographic images, accounting for the efficiency of the scanning, and assuring the storage of scan-records in a standard form, as well as their further digital processing.

The 2-m RCC telescope's Coude-spectrograph of the Rozhen National Astronomical Observatory produces stellar spectrograms that would be processed there by means of the JOYCE-LOEBL microdensitometer. Since the system's software, controlling the device, assures only the general functions of the scanning/recording process, a problem has arisen to develop a specialized one for spectrograms.

To solve the problem, a program package, referred to as SCN, has been investigated in the NAO. Its general purposes are listed in the second paragraph of the paper, the package is briefly described in the third, and a general information on its usage is given in the fourth.

The full description (an user's manual and a source-code listing) of the SCN package is given in the "SCN-MANUAL" and "SCN-CODE" documentations available in the NAO.

2. Purpose

The SCN package is a part of the S software, created in the NAO for processing of coude-spectrograms. The package is intended for an automatical scanning and digital recording of the code-spectrograms on magnetic tapes by means of the JOYCE-LOEBL microdensitometer and represents the first step of this processing.

2.1. *Coude-spectrogram*

Though the SCN can be applied for any spectrograms, it is especially created for the processing of those, obtained on the 2-m RCC telescope's Coude-spectrograph of the NAO. Such a spectrogram (Fig. 1) consists of spectral images of three ob_

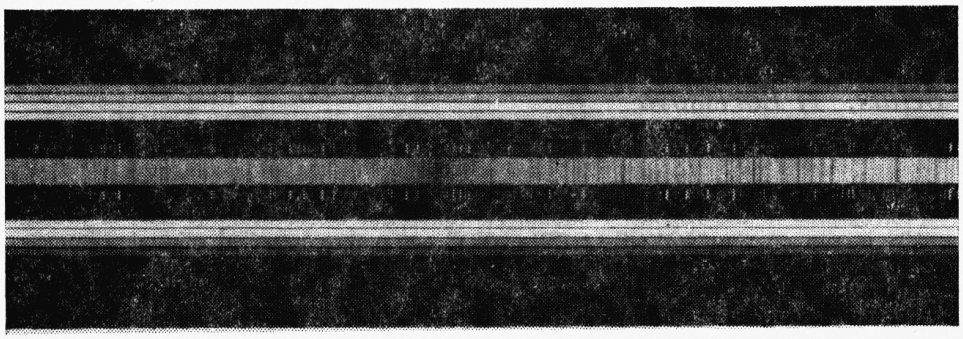

Fig. 1. Stellar coude-spectrogram

jects: of a star, of a "reference spectrum" Fe-Ar lamp, and of a "photometric calibration" Hlgn-lamp.

The "Fe-Ar" produces two bands (upper and lower) on both sides of the stellar spectrum, where as the "Hlgn" — eight or ten bands (a spectrosensitogram) depending on the applied spectrograph's calibration-system. One or more "fog"-bands can be considered as additional bands of the sensitogram.

2.2. *Microdensitometer*

The "JOYCE LOEBL LTD" microdensitometer consists of a MDM-6 measuring device and of a "DATA GENERAL CO" Data Nova 3/12 minicomputer controlling the device by programs written under a special language-interpreter.

The device's measuring plot has two "elementary" steps of moving — 0,0025 and 0,0050 mm (2,5 and 5,0 mm/s velocity respectively); an area up to 250×250 mm$\times$mm can be scanned with a "reading step" that is an arbitrary multiple of the elementary one. Its two-beam photometric system assures the data to be outputted either in transmittancy (as $T\% \times 10$; 0,1% accuracy), or in photometric density ($D \times 1000$). Four ranges for the D are available; from $D=0$ to $D=1$, to $D=2$, to $D=3$, and to $D=4$ (0,001D, 0,002D, 0,003D, and 0,004D accuracy respectively). The user can pick up from a standard set of measuring slits or use a width-adjustable one. The scanning pixel (on the plate) is formed by changeable objectives.

The DG Data Nova 3/12 minicomputer operates under the DOS system ("Diskette Operating System", 1976); it has a 32 Kw (16-bits words) main memory, a dual floppy-disks drive, a magnetic-tape unit (800 BPI), a terminal, a line-prin-

ter and a plotter. The system's software includes some translators, particularly, a special interpreter ("WIZARD", 1980) and a FORTRAN compiler ("NOVA-LINE FORTRAN IV", 1975).

2.3. *FITS format releases*

As a result, the SCN package stores the spectrogram-scans on a magnetic tape. The format FITS (W e l l s, G r e i s e n, 1981) is used as standard for the records. Its release "STANDARD" is created in the NAO — each scan is recorded on the magtape in a separate file (ending with an EOF-mark), the files are created in sequences as the scanning proceeds, the last file ending with an EOV-mark (double EOF).

```
01 SIMPLE    =                T / STANDARD FITS FORMAT:
                                  "SCN" FEB-87
02 BITPIX    =               16 / 2 BYTE TWOS-COMPL INTEGER:
                                  16 BITS
03 NAXIS     =                1 / 1 AXIS (SINGLE-DIMENSION-SCA-
                                  NNING)
04 NAXIS1    =            30001 / NUMBER OF PIXELS IN THE AXIS
05 ORIGIN    = 'BNAO-ROZHEN'    / BULGARIAN NATIONAL ASTRON.
                                  OBSERV.
06 TELESCOP  = '2M-RCC/COUDE'   / OBSERVING INSTRUMENT
07 OBJECT    = '2KO103    HD108 '  / THE IDENTIFIER (PLATE, OBJECT)
08 ALPH-OBS  = ' 00/05/04 '     / OBS. RIGHT ASCENSION
                                  [HH/MM/SS]
09 DELT-OBS  = '+63/34/22 '     / OBS. DECLINATION [DD/''/""]
10 TIME-OBS  = ' 22/00/20 '     / OBS. UT-MOMENT [HH/MM/SS]
11 DATE-OBS  = ' 80/10/23 '     / OBS. UT-DATE [YY/MM/DD]
12 DISPER    =              9.0 / PLATE'S ROUGH DISPERSION
                                  [A/MM]
13 INSTRUME  = 'BNAO — JOYCE-LOEBL' / SYSTEM WHICH SCANNED THE
                                  OBJECT
14 DATE      = ' 83/05/22 '     / DATE THE DATA SCANNED
                                  [YY/MM/DD]
15 BSCALE    =          0.001   / PHOT. DENSITY = DATA *
                                  BSCALE
16 CDELT1    =         0.0050   / INCREMENT ALONG X (X-STEP)
                                  [MM]
17 WAVELENG  =           3475   / FIRST'S FEAR-LINE-WAVE-
                                  LENGTH [A]
18 COMMENT   : OBSERV. EXPOS. = 74:40 [m:s], SP-SLIT= 6*0.25 [mm], SEEING="3.0"
19 COMMENT   :      EMULSION =103aO, unsensitized (MWP-2, 10 [min])
20 COMMENT   : SCANNING PIXEL=SLIT/27.5: WIDTH=0.275 [mm], HEIGHT=10.0
                                  [mm]
21 COMMENT   :      FEAR-HEIGHT=2 * 15.2 [mm], HLGN-HEIGHT=3.5 [mm]
22 END
```

Fig. 2. SCN standard-header

Logically, each file includes a leading record (header) and scan-data. The header represents a 2880-ASCII-characters text (forming 36 rows of 80 characters) with an appropriate information on both the spectrogram and scanning (the Fig. 2 gives a real example of the standard-header). The scan-data follow immediately — each reading is recorded as an integer (twos-complement, two-byte word; first byte — higher order), according to the photometric scale used (see 2.2).

Physically, a tape-file consists of blocks of 1440 words (2880 bytes) each. The first block is the very header, the rest contain the scan's data; the last block is complemented with zeroes, if not filled up with scan-data. As this format is quite dif-

ferent from the one accessible for the WIZARD, the SCN temporarily stores the scan-data on a disk-file and then reformats and copies them to the tape.

In order to reduce the scanning/recording duration, an internal release of the FITS, referred to as "DG—DOS", has been created. It differs, physically, from the "STANDARD" in two things: all the scans of the particular spectrogram are recorded on the tape-file, and blocks of 257 words are used (the last two words are system-reserved and unusable). The last block of each scan in the file is complemented with zeroes, as above. This format is physically identical with that of the DOS, so the recording is carried out directly on the tape during the scanning. By means of the S software's FRM program (B e l l a s, in preparation), created and running on the DEC PDP 11/34 minicomputer of the NAO, such files can be reformatted to the "STANDARD", and vice versa.

3. Software

The SCN program package consists of two programs: SPC and SWZ, and of two "options": a "command-file" SCN.MC, and an "imitator" of the package's editing functions — the SCN.FTN program. The first three run on the Data Nova 3/12, whereas the last one — on the PDP 11/34 minicomputer of the NAO.

3.1. *SPC program*

The SPC program has two general functions. It initializes a scanning session in a sense that by interactive dialogue with the user it carries out the inserting and editing of suitable parameters for both the spectrogram and scanning, and then creates (or updates) special diskette-files ("H" with the scan-file's header, "C" with the scan-controller), necessary for interface between the SPC and the SWZ. If the program is reactivated after the scanning, it carries out a pseudo-graphic visualization of the scan-data (for a general check up); then, if the "STANDARD" format has been fixed, it additionally reformats and copies on the magtape the header (file "H") and scan-data (temporary file "D"; see below).

The SPC is written in FORTRAN IV ("NOVA-LINE FORTRAN IV", 1975) and consists of a main program and three subprograms: SINIT to initialize the hea-

```
        *** SINIT                                    ; initialization of the header's and of the
        *                                              controller's contents
        *           **** ADE *** CVE ; editing additional parameter — and com-
        *           *                                  mentary-rows for the header
        *           **** OBE *** CVE ; editing observation-parameters about the
        *           *                                  spectrogram for the header
        *           **** SCE *** CVE ; editing parameters about the scanning for
        *                                              the header
SPC *******  SEDIT ****
        *           **** WIE *** CVE ; editing parameters about the scanning for
        *           *                                  the controller
        *           **** HLP         ; miscellaneous help-information about the
        *           *                                  editing
        *           **** EXI         ; final check up, scan-mode chart, files ("H"
        *                                              and "C") updating, and exiting
        *
        *           **** DSP         ; spectrogram's scan-bands visualization
        **** SCOPY ****
                    **** FRM         ; disk-to-tape reformatting ("STANDARD")
```

(*the "CVE" extracts command-parameters and parses them to the called it module*)

Fig. 3. SPC program's modules

der and controller, SEDIT to edit their parameters, and SCOPY to visualize and optionally to reformat the scans (see above); the last two, on the other hand, use special subroutines to carry out their particular functions (see Fig. 3). Because of the limited memory size, the task is created using the overlay structure of loading, that the DOS supports; it includes the root "SPC.SV" and the overlay "SPC. OL" task-image files.

3.2. *SWZ program*

This program carries out the very scanning (according to the controller's parameters taken from the special-file "C") and the recording of the scan-data. The latter are stored either in a temporary diskette-file "D" if the "STANDARD" format is fixed, or directly on a tape-file (just after the header, SWZ copied from the special diskette-file "H") for the "DG-DOS" format.

The SWZ is written under the interpreter ("WIZARD", 1980) and consists of a main module (input/output files general maintenance, initialization of the device for scanning), and of a subroutine that performs the scanning and recording of a particular spectrogram-band. By means of the interpreter, the task is created as an executable module "SWZ.SV".

3.3. *SCN options*

A special command-file SCN.MC has been created that, once started automatically loads the two programs in a repeated sequence. This "tasks-swapping" is particularly useful for scanning-sessions of a number of coude-spectrograms, without resorting to a "manual" run of the SPC and SWZ.

An imitating program has been evolved for the package, as well. It is run on the PDP 11/34 minicomputer and is written in its FORTRAN IV Plus ("PDP-11 FORTRAN", 1979). It is only intended for tuition. Because an user interacts with the SCN mainly during the editing of the header and controller, all the functions of their parameters initialization, editing, and verification (see the 4.3) are included in the SCN.FTN imitator program; but, of course, no scanning/recording, nor visualization are performed. Its task-image file SCN.TSK is created under the control of a command-file SCN.CMD using an overlay structure of task-building that is determined by an overlay-description file SCN.ODL. The "imitator" creates, in addition, a text-file SCNIMI.TXT with an exact copy of the whole program/user dialogue. This file can be printed out after the program completes.

4. Usage

The processing of a spectrogram by the program package includes a preliminary preparation of the measuring device and of the spectrogram, and the running of the SCN.

4.1. *Preparation*

This includes two stages. The first is the positioning of the measuring device's plot with the spectrogram on it. An alignment must be carried out manually so that the direction of the spectrogram's wavelength-scale to coincide with the x-axis of the device, and then the zeroing of the very axis is performed. This has to be done either at the center of a preliminary chosen "reference-spectrum" Fe-Ar lines, or at 0,01 mm backward (a table of recommendable Fe-Ar lines is given in

the documentation). Then, the y-axis is zeroed at the middle of the star-band. Finally, the y-positions of the other bands, to be scanned, have to be determined.

The next stage consists in adjustment of the photometric system. The user chooses the appropriate combination of slit and objective (the stellar and Fe-Ar bands must be scanned with one and the same slit, but it can be changed for the spectrosensitogram; see below). Then, the desired range is to be switched on (see 2.2) and the photometric-zero must be set (recommendable on a clear plate); the x-y-coordinates of the photometric-zero pixel must be determined.

Finally, a set of parameters about both the spectrogram and scanning is to be prepared. These are: coordinates and exact time of observation, spectrogram's rough dispersion, relative intensities of the spectrosensitogram's bands, and identifier (plate and star) about the spectrogram. About the scanning these are: scan-engthh and reading-step, starting Fe-Ar line's wavelength (coded so as to "fix" the x-zeroing type), photometric-zero pixel coordinates, and the ordinates and identifiers (object and scan) of the particular bands to be scanned.

4.2. *Running*

It is recommendable to run the package by the command-file. It starts the program SPC, initializing both the header and controller. The very initialization is performed solely if there are no special files "H" and "C"; only in this case the user is free to fix the output-tape files format (either to "STANDARD" or to "DG — DOS"). Else, the files are used as an initial set up.

The SPC's "editor" module is then activated. Under its control, by an interactive-dialogue, the user inserts and/or updates the particular parameters for both the header and controller (see 4.3). Finally, a scan-mode-chart (Fig. 4) is displayed to illustrate the arrangement of the scanning, to be carried out, and the "H" and the "C" files are created (overwritten if they already exist).

```
XEND [MM]    STEP        XORG [MM]       PLATE
150,0000      0,0050          0,0000  '2K-0103
              OBJECT              SCAN    YORG  [MM]
    <====='HLGN-2000    '=====+  04     0,5600
    <====='HLGN-0500    '=====+  05     0,4500
    <====='HLGN-1560    '=====+  06     0,3600
    <====='HLGN-0700    '=====+  07     0,2500
    <====='HLGN-FOGU    '=====+  08     0,2000
    <====='FEAR-.UP.    '=====+  02     0,1450
    <====='HD 108       '=====+  01     0,0000
    <====='FEAR-DOWN    '=====+  03    —0,1500
    <====='HLGN-FOGD    '=====+  09    —0,1900
    <====='HLGN-0450    '=====+  10    —0,2500
    <====='HLGN-1000    '=====+  11    —0,3500
    <====='HLGN-1400    '=====+  12    —0.4600
    <====='HLGN-1800    '=====+  13    —0,5600
XPHO=     1,0000,    YPHO=   —0,5000  [MM]
```

Fig. 4. SCN scan-mode chart

The following procedures depend on the fixed format. If the "STANDARD" is fixed, for each band of the spectrogram, sequentially as fixed by the controller, the very scanning (the SWZ is automatically started by the command-file) and the visualization and reformatting (the SPC is reactivated) are carried out, as follow. Using proper control-parameters, the SWZ performs the scanning of the band and the recording of the data on a temporary diskette-file "D"; if this is the first band of the spectrosensitogram (and if this option has been fixed in the controller),

the user is asked to change the slit and to reset the photometric-zero prior to scan it. Then, the SPC's module for scan-bands visualization (under request for a Hlgn-band) is activated. Finally, the module for reformatting, that copies the scan-header ("H" file) and the scan-data ("D" file) on the tape, is run.

If the "DG—DOS" format is fixed, the SWZ performs the scanning and the recording of the spectrogram bands, all at once, directly on the tape (each scan with its header copied from the "H" file and properly updated). The slit changing is also assured, like above. After completing the scanning, the SPC is restarted to visualize sequentially all the scans (the Hlgn-bands under request).

No matter what the output-format is, after the processing of the whole spectrogram, the "editor" module (SPC program) is reactivated. Now, if the user desires, he may define the scanning of another spectrogram. Since both the header and controller are already updated, only some of the parameters have to be edited.

4.3. *Editor*

The most important stage of the user's interaction with the SCN package is the parameters insertion or updating in order to define the spectrogram and the scanning. This is carried out in an interactive-dialogue by the editor-module of the SPC program. The particular function of the editor is activated by an appropriate command inserted as answer to a "ready" prompt; the command-string is analysed and if it is allowed, the fixed function is executed and a verification is made. In case an error occurs, a proper error-message is displayed, instead.

The commands have a standard format; each consists of a code, a switch, and one or more parameters. The command-code determines the general function. These are five, namely: the editing of additional (to the standard header) parameters or comments, the displaying of miscellaneous help information, the editing of header's parameters about the spectrogram, the editing of header's parameters about the scanning, and the editing of parameters for the controller. The switch is an option, that fixes the particular function. Appropriate data to update the header's and/or the controller's contents can be inserted by optional user's parameters following the particular switch. In case if either the parameter or both the parameter and switch are omitted, the particular part of the header or controller, the command is concerned with its parameters, is displayed.

A special command is provided for editing exit. If it is typed, all the necessary parameters are checked up whether they are already set and if yes, a scan-mode chart (Fig. 4) is displayed and the user is asked to confirm the exiting, in which case, finally, the "H" and "C" files are created (overwritten if already exist) and the editing is completed. Otherwise, and in case when the check-up fails, the editor remains active (in the latter case a proper error-message is displayed about the missing parameters).

5. Conclusions

The SCN program package assures a high-level automated process of coude-spectrograms scanning/recording in the NAO by means of the JOYCE-LOEBL microdensitometer. The recording on magnetic tapes allows the further digital processing of the spectrograms. The "STANDARD" release of the FITS-format makes possible the easy transportation of scan data to other astronomical institutes.

The SCN allows the scanning of up to 20 bands of a fixed plate with a minimal step of 0,0025 mm and maximum number of readings 65535 per scan-band. The scanning/recording for spectrogram of 15 bands, of 100 mm each, with 0,0100

mm reading-step takes about 30 min in "STANDARD" format and about 15 min in "DG — DOS".

The documentation and the imitator program helps the user to learn in details the usage of the package without wasting the time of the microdensitometer. On the other hand, the set of allowed commands, the runtime help information and the error-messages, gives enough tools to prepare a scanning session, the scan-mode chart shows "how the scanning will be carried out", and the rough-graphic visualization — "what has been really recorded".

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