EUROPEAN SOUTHERN OBSERVATORY

BULLETIN NO. 12

The Governments of Belgium, the Federal Republic of Germany, France, the Netherlands, and Sweden have signed a Convention[1]) concerning the erection of a powerful astronomical observatory on October 5, 1962.

By this Convention a European organization for astronomical research in the southern hemisphere is created. Denmark became a member of the organization on June 1, 1967. The purpose of this organization is the construction, equipment, and operation of an astronomical observatory situated in the southern hemisphere. The initial programme comprises the following subjects:

1. a 1.00 m photoelectric telescope,
2. a 1.50 m spectrographic telescope,
3. a 1.00 m Schmidt telescope,
4. a 3.60 m telescope,
5. auxiliary equipment necessary to carry out research programmes,
6. the buildings for administration, laboratories, workshops, and accommodation of personnel.

The site of the observatory is in the middle between the Pacific coast and the high chain of the Andes, 600 km north of Santiago de Chile, on La Silla, at an altitude of 2400 m.

The geographical coordinates of the main summit of La Silla are

$$\lambda = +70^\circ\,43'\,46''.50$$
$$\varphi = -29^\circ\,15'\,25''.80.$$

They were determined by the Instituto Geográfico Militar of Santiago/Chile.

1) The ESO Management will on request readily provide for copies of the Paris Convention of October 5, 1962.

Organisation Européenne pour des Recherches Astronomiques
dans l'Hémisphère Austral

EUROPEAN SOUTHERN OBSERVATORY

BULLETIN NO. 12

June 1975

Edited by European Southern Observatory, Office of the Director-General
Bergedorfer Straße 131, 2050 Hamburg 80, Federal Republic of Germany

ESO BULLETIN No. 12

CONTENTS

THE GRANT MACHINE

J. Rickard, W. Nees, and F. Middelburg

I. Introduction

ESO-Chile has had in operation an automated Grant comparator-microdensitometer for about five years. The machine has two principal functions:

(a) the accurate measurement of the positions of stellar lines for radial velocity (RV) determinations,

(b) microdensitometry (MD) of stellar spectrograms.

The data acquisition and control system is based on an HP 2100 computer and can provide printed page, punched tape and magnetic tape recordings of the digitized output for both machine modes. There is also a strip-chart recorder for manual measurements. This automation has increased the speed and accuracy of spectral plate measurements, has eliminated human error to a great extent, has saved the astronomer valuable time—thereby increasing his research potential—and has provided the data in a form convenient for further computer reduction and analyses.

II. The measuring machine—Grant Model 800

II.1. Specifications

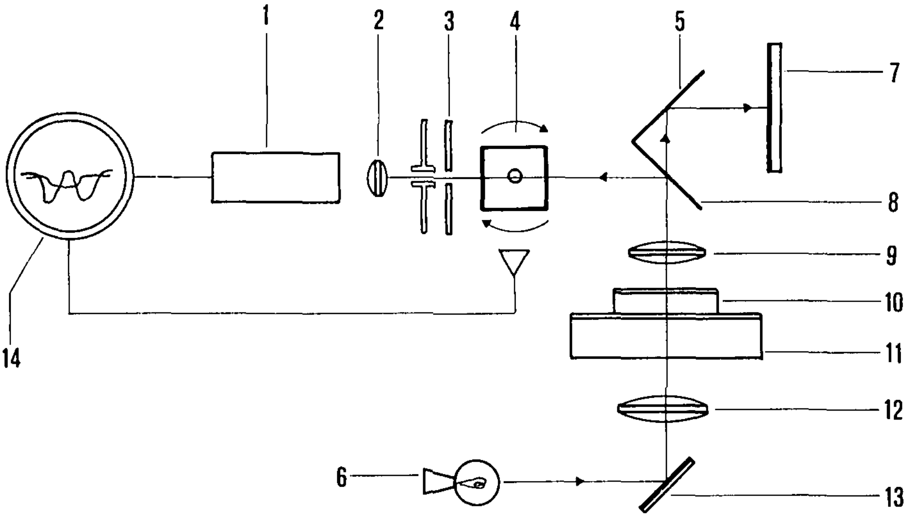
The manufacturer's specifications have been met in our particular case. The backlash of the X and Y screws is less than 1 μm; settings are repeatable to 0.5 μm; the over-all measuring accuracy is better than ± 1 μm/250 mm. Spectra can be projected to the analyzing slit with a variety of magnifications.

Plates as long as 450 mm in X and 100 mm in Y can be accommodated. There is a variety of scanning und slewing motors which will be described below.

II.2. Optical configuration—RV mode

The optical configuration of the Grant Model 800 for RV measurements is given in Fig. 1.

Light passes from the lamp through a collimator to the glass table and spectrum. The image of the spectrum is formed by the lens on the analyzing slit and a viewing screen, the light being split by a semi-transparent beam splitter. The image of the spectral line is swept across the slit by means of a rotating planar transparent block. The signal from the photomultiplier (PM) is scanned across the CRT screen in both forward and reverse directions, using a signal from a second PM looking at a lamp through a chopper synchronized with the rotating block. When the spectral line is in the centre of the slit, the forward and reverse CRT scans coincide. In this manner the position of the line can be accurately determined.



1 Photomultiplier
2 Lens
3 Masks
4 Rotating scanner
5 Mirror
6 Lamp
7 Viewing screen
8 Beam splitter
9 Lens
10 Plate
11 Table
12 Collimator
13 Mirror
14 Oscilloscope

Fig. 1

Plate 1 shows the Grant machine. The two wheels are the manual controls for the X (the right wheel) and Y (the left wheel) motions of the table. The measuring slit and scanner are mounted in the head. The CRT screen is seen on the left side of the measuring head. The X-encoder is the extension on the screw mounted on the left. One of the drive motors, the AC-synchronous motor, is the extension on the right.

Plate 2 shows the details of the machine being used to measure line positions with the CRT display. The stellar spectrum is seen projected in the screen on the right. The dark comparison line falling between the two fiducial lines is centred and being scanned by the rotating block. The forward and reverse scans coincide, thus determining the line's position.

The Grant machine

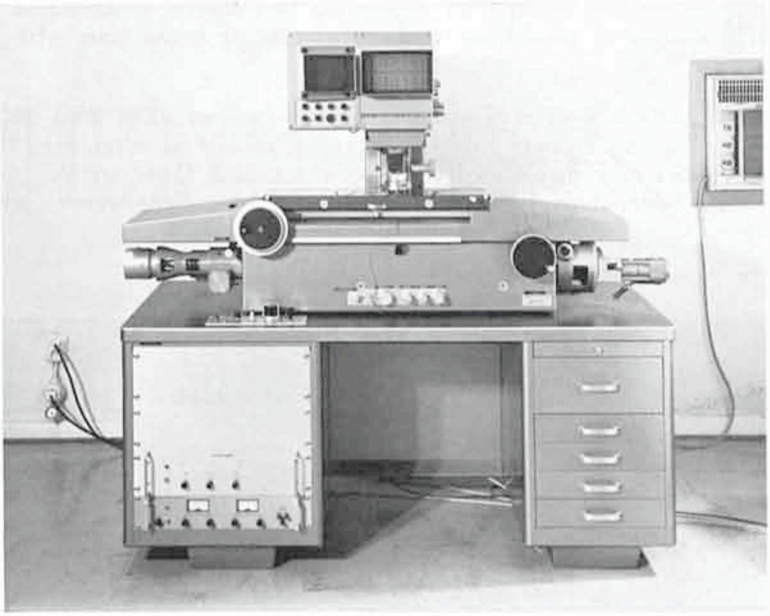


Plate 1

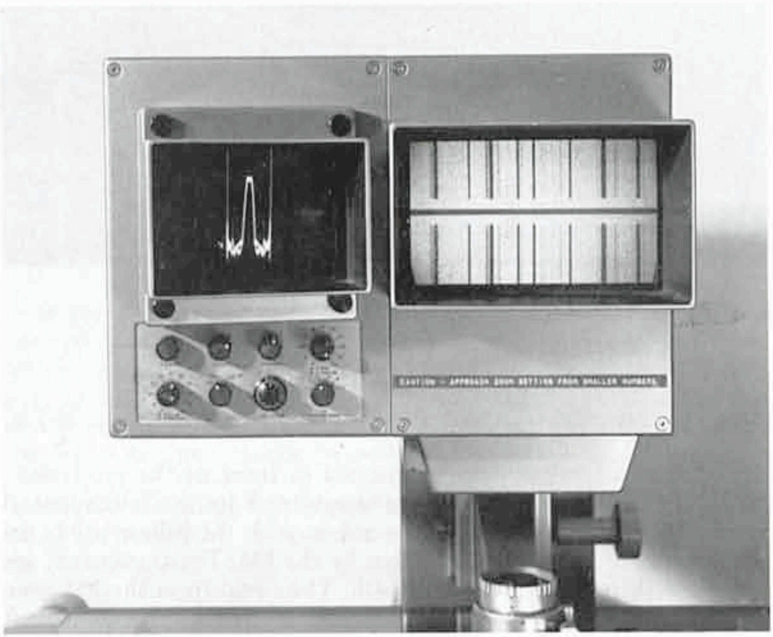


Plate 2

The width of the line on the CRT display can be stretched or diminished electronically, making it possible to measure narrow or broad lines with equal accuracy.

In addition, there is a series of masks which can be inserted to limit the measurement to upper or lower halves of the line, middle or edges, etc. Plate 3 shows the series of controls used to adjust the masks. There are also control levers on the table which allow the operator to switch rapidly between star and comparison, upper and lower half of spectrum, etc.

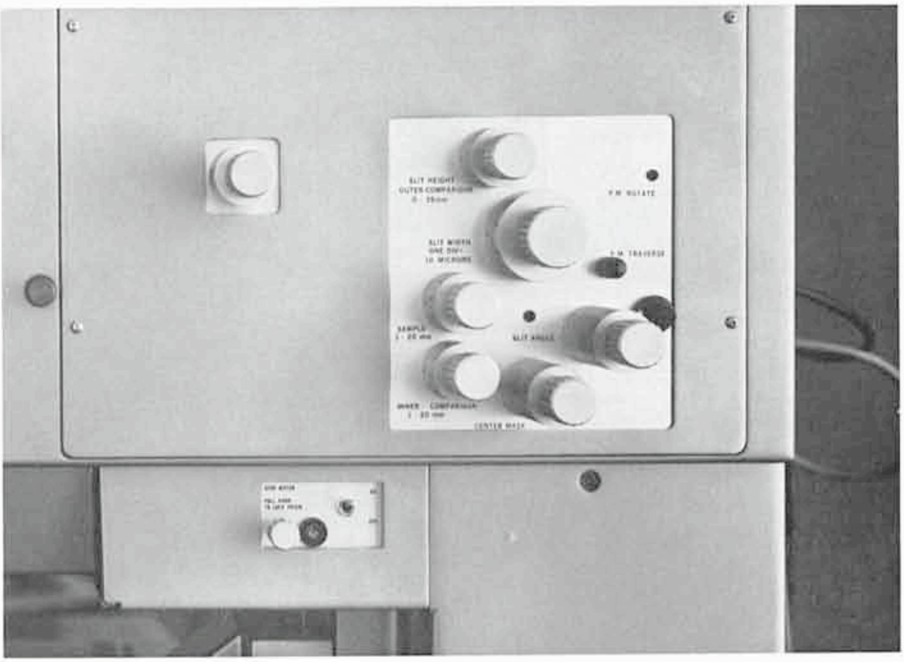


Plate 3

II.3. Optical configuration—MD mode

The optical configuration for the microdensitometer mode is given in Fig. 2.

A preslit assembly of yellow glass is inserted in front of the projection lamp. The image of the preslit is formed on the spectrum by the lower lens. A blue filter in front of the photomultiplier combines with the yellow preslit to form the equivalent of an opaque preslit as seen by the PM. The transparent scanning block is fixed with respect to the light path. The signal from the PM goes to an amplifier. The CRT display cannot be used. Plate 1 shows the controls for the preslit assembly in the lower middle part of the machine.

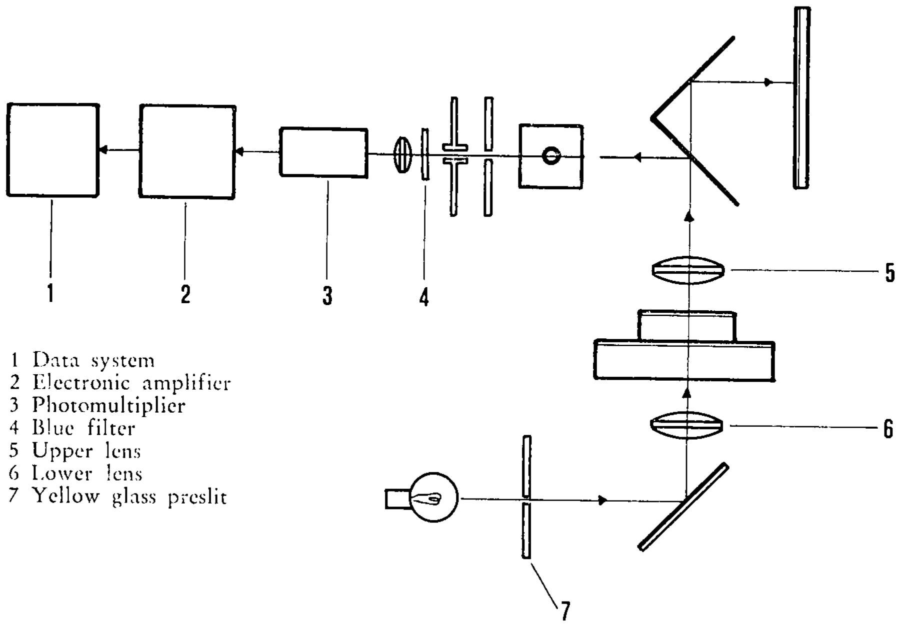


Fig. 2

III. Motor drives available

The X-motion of the table is controlled by four motors. Two are AC-synchronous motors with four discrete speeds. Motor A has speeds $^1/_2$, 1, 2, and 4 mm/min; motor B, $^1/_4$, $^1/_2$, 1, and 2 mm/min. Since the speed $^1/_4$ mm/min is never used, motor B is superfluous and is normally not attached to the machine.

The speeds provided by motor A are used only for non-computer scanning, i.e. strip-chart recording in the microdensitometry mode. This is due to the fact that the automatic digitization can be done, in principle, without resolution loss up to speeds of 30,000 samples/s. For strip-chart recording, however, the resolution is limited by the time constant of the strip-chart recorder itself, and speeds of over 4 mm/min cannot be used.

A variable-speed reversible DC motor, with a range of 8 to 80 mm/min is also provided. This is used by the computer control programme during automatic scanning.

The fourth motor is a reversible DC motor with a speed of 420 mm/min, used for rapid slewing of the table by manual or computer control.

IV. The configuration of the data acquisition and control system

Fig. 3 shows the system block diagram and Plate 4 the actual hardware arrangement. The numbers in the photograph correspond to the components listed in Fig. 3. The system includes the following possibilities:

(a) analog strip-chart recording for microdensitometry,

(b) digital recording of X-Y positions,

(c) automatic microdensitometry.

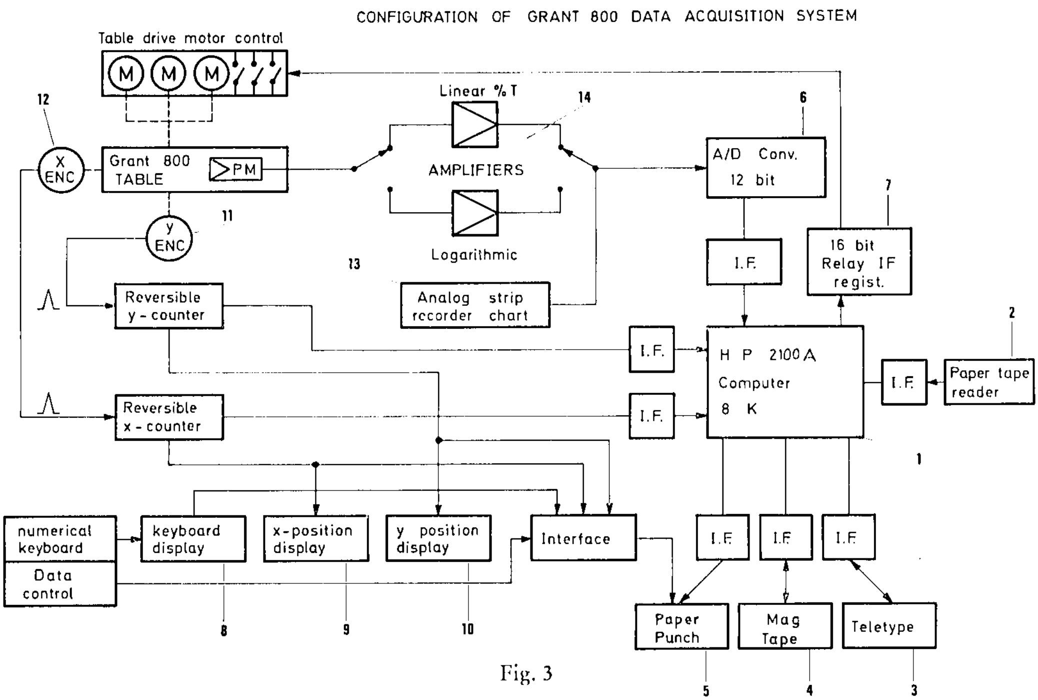


Fig. 3

1 Hewlett Packard 2100-8K
2 Optical paper tape reader HP 2748
3 Teletype ASR-33
4 Magnetic tape HP 7970 9-Track NRZI compatible 800 BPI
5 Paper tape punch Facit 4070, 8 hole, 70 ch/s
6 A/D convertor HP 2310C 12 bit 100 ns conversion
7 Relay register interface—16 contacts
8 Numerical display interface
9 X-position display—resolution 1/5 μm
10 Y-position display—resolution 1 μm
11 Heidenhain shaft encoder—1000 pulse/rev.
12 Heidenhain shaft encoder—5000 pulse/rev.
13 Strip-chart recorder
14 Density (logarithmic) and transmission (linear) amplifiers

Plate 4: The numbers here are the same as in Fig. 3.

IV.1. Analog recording

Strip-chart recordings of either % transmission or optical density can be made by recording the output of either a linear or logarithmic amplifier. The accuracy of this type of tracing is dependent on the amplifier's accuracy and stability. The sensitivity of the linear amplifier is specified as 0.1 % of full scale between plate transmission values of 5 to 80 %. Zero drift should be less than 0.3 % in two hours. These values may be a bit optimistic since some fluctuations in the PM output are not included in the specifications. Analog recording is not done on a regular basis owing to heavy demand for the machine.

IV.2. Digital recording of X-Y

It is possible to record on paper tape the X and Y positions of the table. The two encoders are connected to an interface which controls the paper tape punch. A numerical keyboard allows the operator to insert a 6-light code number and record either the X or X and Y encoder readings in ASCII code (8-level) on paper tape. This option is used for radial velocity measurements. The operator moves the table manually and stops at whatever lines he desires, and then records the positions.

In practice, this keyboard is not used very often, since more versatile measuring schemes can be provided by computer programme. The teletype can be used instead of the keyboard, allowing alpha-numeric data to be inserted. Several programmes have been written for specific tasks providing setting averages, differential shifts, and other on-line capabilities.

IV.3. Automatic measuring—MD mode

The HP 2100 computer acts as the controller during the automatic data acquisition. It controls the motion of the table through a 16-bit relay register interface card. A computer word can be output to the relay register by simple programming to effect the various forward and reverse motions necessary.

Programmes are read into the computer by a high-speed tape recorder. The computer has the option of logging the data on the teletype, the paper tape punch, or the magnetic tape unit. The X and Y counters are readable by computer also.

The analog signal coming from either amplifier is digitized on a scale O → 2047 (11 bits). This provides 0.05 % digitization accuracy, which is quite sufficient. The A/D converter has an aperture time of 110 ns and can be used up to speeds of 30 K digitization a second. At the fastest scanning speed (80 mm/min) with the highest resolution (15 μm) the digitizer is working at only one quarter of its capacity. No smoothing occurs owing to rapid scanning, since the aperture time is so short.

The actual scanning of the plate is accomplished by moving the table with the "variscan" DC motor at a speed of about 40 mm/min. The speed was chosen to minimize mechanical stresses on machine and motor. A fixed number of digitizations are made and stored in a buffer in the computer. When the buffer is full, the table is stopped, to allow time to output the data onto magnetic tape or another output device. The table must be stopped for output onto magnetic tape, since the output operation cannot be interrupted, i.e. one cannot continue digitizing while the magnetic tape is writing. The computer is not equipped with the direct memory access option that might make continuous scanning possible.

If there were no mechanical overshoot in the motion of the table, it would be possible to continue scanning the next block by restarting the variscan motor. In practice, the table must be reversed to come back to the last digitized point and then restarted in the forward direction. This method ensures that no data are lost.

The over-all speed for measuring a plate depends upon the length, resolution, number of clear plate measurements, etc. Typical values are the following:

Length of spectrum ESO coudé camera II:	75 mm
Resolution:	3 μm
Block size:	500 samples
Table speed:	40 mm/min
Time to scan one block, convert to IBM-compatible BCD, and record:	6 s
Time to digitize entire spectrum:	5 min

In practice, much more time is spent aligning the plate, choosing the regions to be scanned, adjusting the amplifiers, etc.

Thus the speed of measuring the plate depends on the operator and his desires. A good operator can average two plates/hr.

V. Description of the scanning programme GR1B

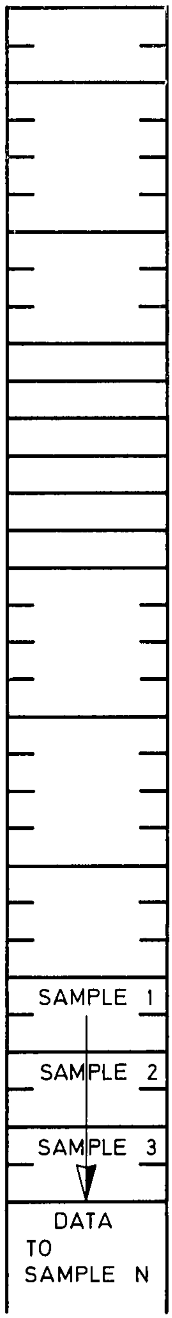
V.1. General description

With this programme the HP 2100 computer can be used to drive the Grant machine to scan partly or wholly a photographic spectrum.

The photometric values of the points measured, with their X and Y coordinates, codes, slit dimensions and resolution, are stored on magnetic tape. The regions which have to be scanned, as well as the resolution, can be specified by the user. The data thus acquired can later be used on another computer for data reductions. The formatting and coding of the magnetic tape ensures an easy input at any computer centre equipped for IBM-standard 9-Track 800 bpi NRZI.

J. Rickard, W. Nees, F. Middelburg

MAGNETIC TAPE DATA FORMAT



Serial No. 4 characters (each word = 2 characters)	(right justified)
Identification 8 characters	(left justified)
Date 6 characters	(left justified)
Code 2 characters	(left justified)
Slit-height 2 characters	(left justified)
Slit-width 2 characters	(left justified)
Resolution 2 characters	(left justified)
Log. or Lin. ampl. 2 characters	(0 = Lin 1 = Log)
Always 0 for no conversion	(right justified)
Free 8 characters	(all spaces)
X-encoder (F 8.0) Reading of first photometric value	(right justified)
X-encoder (F 6.0) Reading of first photometric value	(right justified)
Photometric value each 4 characters integer (I4)	(right justified)

N=block size

Fig. 4

The programme is written in an HP assembler which gives fast execution and efficient use of core memory space. HP-provided drivers are used for input and output of the teleprinter and output on the magnetic tape. Simple non-interrupt drivers are used for the input from the Z-encoder and the A/D converter.

The X-encoder is read in as a constant check on the position of the table. The A/D converter digitizes the plate at a certain X-value, while the computer is always checking the real position of the table to ensure that small errors do not become cumulative. This is important at the high scanning speed used.

The X-encoder has a maximum of seven decimal digits which, when converted to a binary integer, will not fit into a single 16-bit computer word. Therefore, two computer words are used for all calculations concerning the X-encoder, both of which are used as integer numbers. The carry-over of bits from one word to another is done by our own software.

The output on the magnetic tape consists of fixed-length records of which the first 26 words give the information which will be necessary for later reductions, and the rest is filled up with a list of photometric values. Fig. 4 shows schematically the format of one physical record on the magnetic tape.

Although a binary code would have been the most efficient way to store the data on tape, it was felt that, because of the variety of computer hardware, it would be best to output in the EBCDIC code. This 8-bit code should ensure maximum compatibility between our and other computers in Europe.

V.2. GR1B in operation

(Refer to flow chart Fig. 5)

1. The teletype (TTY) asks on which file of the magnetic tape the measurements are to start. Therefore it is possible to continue using a tape which already has data stored from previous runs. The user decides where the end-of-file marks are to be written. He forward-spaces the tape by simply typing the number of the file he wants to use.

2. The TTY asks for the *block length.* During the scanning a buffer will be filled with photometric values: when this buffer is full, the table will stop and the contents of the buffer will be dumped on magnetic tape. The size of this buffer is given by an integer number between 1 and 500. Normally a buffer of 500 will be used; only if single lines are measured will it be more efficient to use a smaller buffer size.

3. The TTY asks for *serial number.* The answer can be given up to four numbers. This serial number is for later plate identification within one file and it is automatically incremented when a measurement is finished.

4. The TTY asks for the *date*; the answer can be given with up to six numbers.

5. The TTY asks for the *identification.* The answer can be given with up to eight alphanumeric characters. This identification could be, e.g., the HD number of the object observed.

6. The TTY asks for *code, slit height, slit width and resolution.*

The *code* may have two alphanumeric characters which could be used to identify clear plate or comparison lines, etc.

The slit dimensions may be described by numbers from 1 to 99.

The *resolution* is the integral number of microns between each point which is to be measured. This may be from 1 to 99 microns.

All these questions (under 6) may be answered by typing /, a slash, which means that any previous answers which were given would remain unchanged.

N. B.: Only the resolution has any effect on the actual scanning, since it determines the digitization interval for the A/D converter. The slit parameters and other identification numbers are merely copies onto magnetic tape.

7. Switch register 0 (zero) should be on if the logarithmic amplifier is used.

8. The *regions* which are to be measured will now have to be specified. The TTY asks for the start and end of each region. These starts and ends are given by setting the table manually to the desired point and pressing the TTY spacer bar. Up to 20 regions may be taken. If the whole plate is to be scanned, only one region needs to be specified. The regions may be given in any sequence and may even overlap.

9. Striking the E key ends this part of the programme.

10. From here on the *computer takes complete control* and will scan all specified regions automatically and put the photometric values, code, etc. on the magnetic tape.

11. The table slews in reverse to the beginning of the first region, it overshoots the beginning, stops and comes forward again, using the variscan motor. As soon as the beginning is found, photometric measurements are set into a buffer at the specified resolution. When the buffer is full, the table stops, the contents of the buffer are dumped on magnetic tape, a check is made to see if the whole region has been done and, if not, the table will reverse to where it took the last measurement, will again overshoot, stop and go forward again to continue from where it left off. When the whole region has been done, the table goes to the beginning of the next region and the process of scanning is repeated.

12. After all the regions have been measured the TTY asks "all scans again?". Answering with a *yes* will cause the questions under 6 to be asked again, the programme will then repeat the process starting from 11. If the question is answered with *no*, the TTY will ask "end of file?". Answering with *yes*

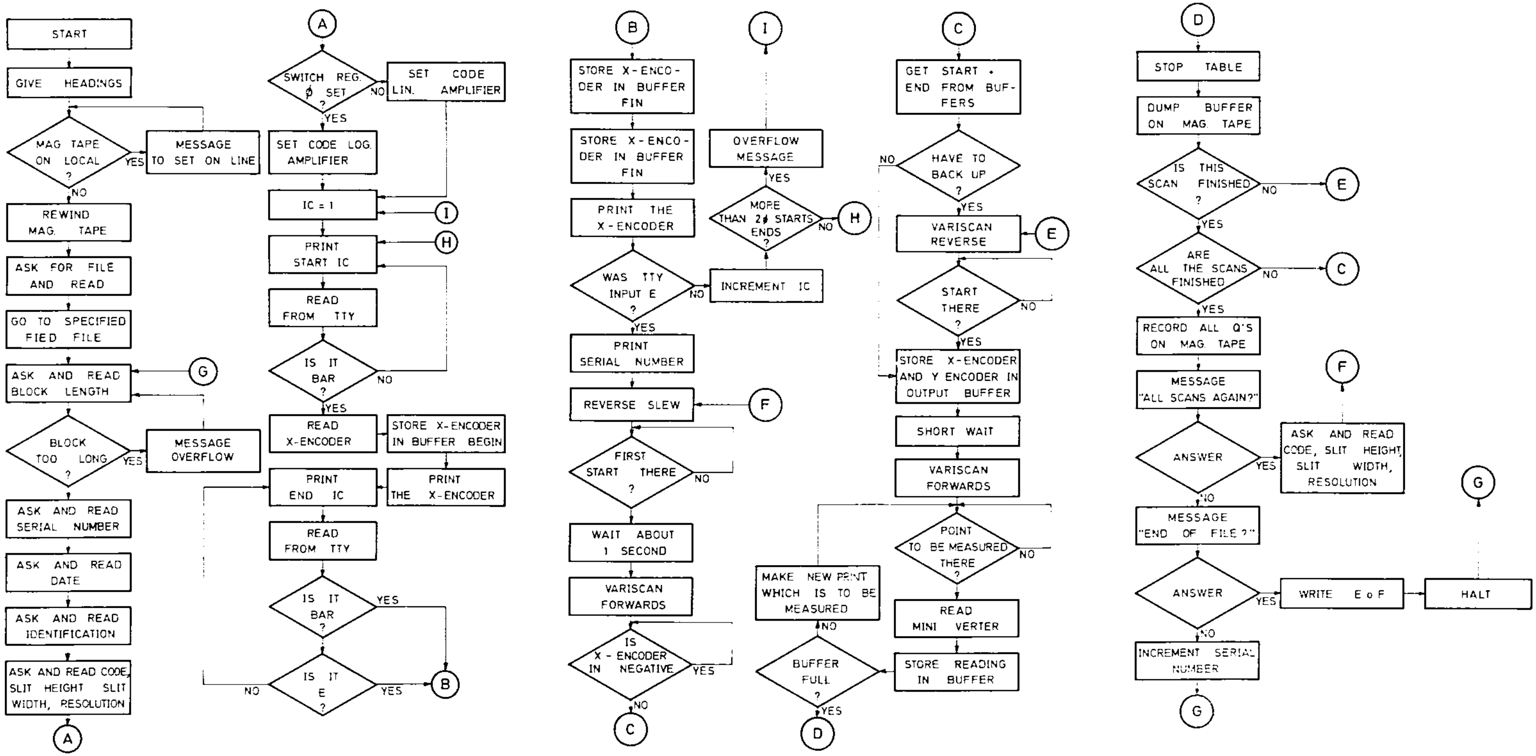

START
GIVE HEADINGS
MAG TAPE ON LOCAL ?
MESSAGE TO SET ON LINE
REWIND MAG. TAPE
ASK FOR FILE AND READ
GO TO SPECIFIED FIED FILE
ASK AND READ BLOCK LENGTH
BLOCK TOO LONG ?
MESSAGE OVERFLOW
ASK AND READ SERIAL NUMBER
ASK AND READ DATE
ASK AND READ IDENTIFICATION
ASK AND READ CODE, SLIT HEIGHT SLIT WIDTH, RESOLUTION
SWITCH REG. ϕ SET ?
SET CODE LIN. AMPLIFIER
SET CODE LOG. AMPLIFIER
IC = 1
PRINT START IC
READ FROM TTY
IS IT BAR ?
READ X-ENCODER
STORE X-ENCODER IN BUFFER BEGIN
PRINT END IC
PRINT THE X-ENCODER
READ FROM TTY
IS IT BAR ?
IS IT E ?
STORE X-ENCODER IN BUFFER FIN
STORE X-ENCODER IN BUFFER FIN
PRINT THE X-ENCODER
WAS TTY INPUT E ?
INCREMENT IC
PRINT SERIAL NUMBER
REVERSE SLEW
FIRST START THERE ?
WAIT ABOUT 1 SECOND
VARISCAN FORWARDS
IS X-ENCODER IN NEGATIVE
OVERFLOW MESSAGE
MORE THAN 2ϕ STARTS ENDS ?
GET START + END FROM BUFFERS
HAVE TO BACK UP ?
VARISCAN REVERSE
START THERE ?
STORE X-ENCODER AND Y ENCODER IN OUTPUT BUFFER
SHORT WAIT
VARISCAN FORWARDS
POINT TO BE MEASURED THERE ?
READ MINI VERTER
STORE READING IN BUFFER
BUFFER FULL ?
MAKE NEW PRINT WHICH IS TO BE MEASURED
STOP TABLE
DUMP BUFFER ON MAG. TAPE
IS THIS SCAN FINISHED ?
ARE ALL THE SCANS FINISHED
RECORD ALL Q'S ON MAG. TAPE
MESSAGE "ALL SCANS AGAIN?"
ANSWER
ASK AND READ CODE, SLIT HEIGHT, SLIT WIDTH, RESOLUTION
MESSAGE "END OF FILE ?"
ANSWER
WRITE E o F
HALT
INCREMENT SERIAL NUMBER

Fig. 5

will cause an end-of-file mark to be written on the magnetic tape, and the computer will halt. Pressing start will cause the programme to start again at 2. Answering the question with *no* will cause the serial number to increment by one and the programme will continue at 2.

VI. Summary

Plate 5 shows the entire Grant machine computer system in operation. The operator sits facing the screen. Messages typed out by the computer and operator instructions are entered via the teletype on his right.

After the initial programme is loaded via the photoreader, the operator need only give his attention to the plate and the measuring process.

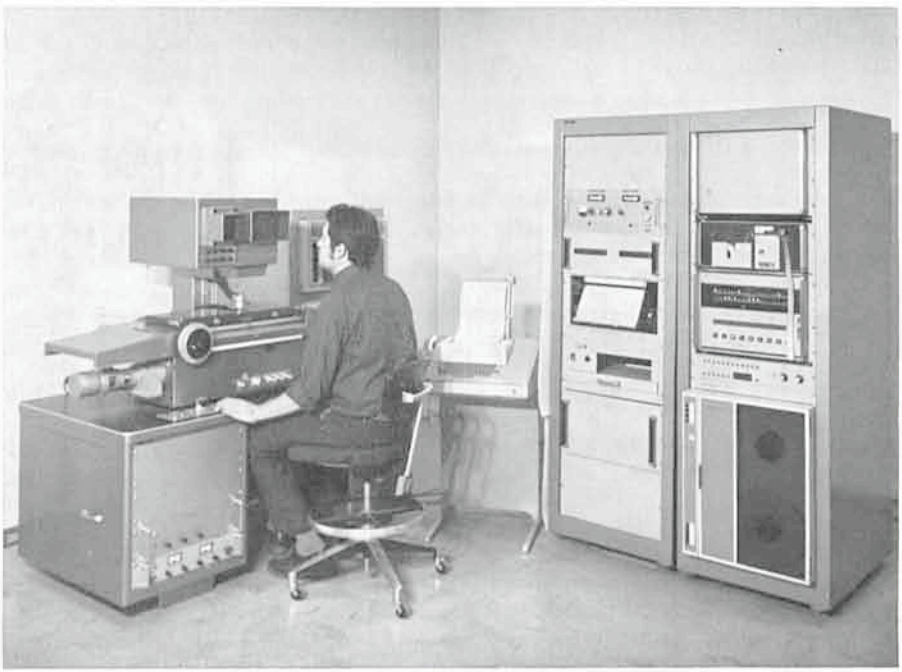


Plate 5

Visitors interested in digitizing the plates they obtain on La Silla must request, in advance, time on the Grant machine. The amount of unused time has diminished considerably since its installation and the schedule usually is full.

In addition to the GR1B programme, described here in detail, the following programmes are also available:

1. GR2B: Magnetic tape output is in binary. Block length is 2,500 samples.

2. DCODE: A tape dump programme for GR1B.

3. ECODE: A tape dump programme for GR2B.

4. RAVIN: An on-line programme which provides the average of several settings on the same line, and a suitably formatted papertape for the programme RADVEL. RADVEL is an off-time programme for calculating radial velocities using dispersion tables.

5. LAMDA: Programme to calculate the apparent wavelengths of lines from their X positions. Programme determines the dispersion curve empirically and not by a table.

6. GENRV: Programme to calculate the radial velocity of each line measured. Lines can be deleted and the mean RV for a plate determined.

Note added in proof: This paper describes the Grant machine as of mid-1972. GRIB has been revised and made more flexible, although the major features remained unchanged. For the latest information about the machine's status, consult the director in Chile.

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THE SANTIAGO GRANT MACHINE AND ZEEMAN COUDÉ DATA REDUCTIONS

H. John Wood

I. Introduction

The ESO Chile long-screw Grant measuring machine, coupled to a small computer for data acquisition, has been used in a programme of line identification, radial velocity determination and the determination of the magnetic fields of stars. It is the purpose of this paper to briefly describe the operation of this system.

II. The Zeeman spectroscopy project requirements

In a programme to determine the magnetic fields of new southern magnetic stars discovered at La Silla, we use Camera III plates taken with the coudé spectrograph of the 1.5 metre reflector. A Babcock-type Zeeman analyzer for circular polarization produces two stellar images on the slit of the coudé spectrograph. Small wavelength shifts between the dextrogyrate and levogyrate spectrograms are a measure of the strength of the longitudinal component of the stellar magnetic field. In addition, the Doppler effect shifts and broadens the stellar lines.

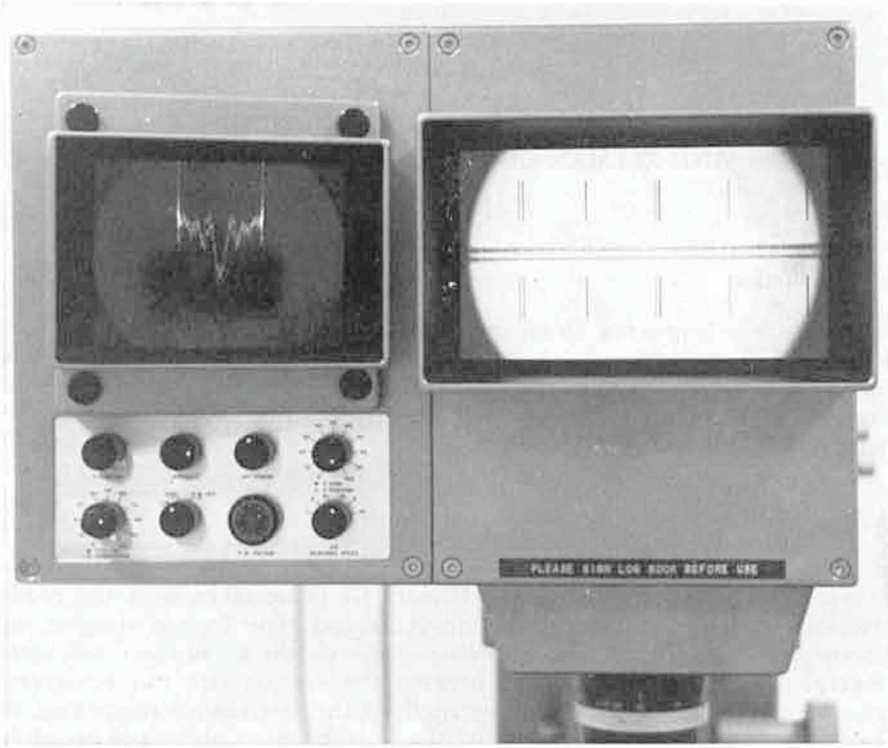
Thus, we must determine the local Doppler shift for the star, the rest wavelengths of the lines for identification purposes, and finally the magnetic field and probable error from the individual line shifts and basic atomic data.

III. Three computer programmes for data acquisition and computation

In the following paragraphs, three computer programmes for the Grant machine will be described briefly. For specific details of the structure and operation of the programmes, consult programming and operating manuals available at ESO Santiago.

A. GRINP. The programme for **Gr**ant machine **Inp**ut to paper tape of digitized screw readings provides averaging and differencing functions. Up to 20 settings on a spectrum line are immediately averaged by the on-line computer on command by the operator. The teletype is used for communication with the computer.

The normal measuring procedure for coudé Camera III Zeeman plates is as follows:



Optical and oscilloscope display of a typical Zeeman spectrogram on the Grant machine. One component of a stellar iron line at 4271 angstroms is being measured.

The spectrogram is set in standard fashion on the Grant machine.

The programme tape is loaded into the computer via the tape photo-reader. The tape punch records one line of plate identification and measuring engine data and is then ready for the screw readings.

Comparison lines are entered with their wavelengths as identifying numbers. Stellar lines are measured in sequence with the comparison lines but with arbitrary alphanumerics as identification. For Zeeman plates, the ordinary ray is measured first and the same identifier number is used for the extraordinary ray. When the computer detects a second stellar line with the same identifier number, it automatically differences the two average screw readings, thus providing the Zeeman shift in microns.

The final tape produced by **GRINP** thus contains identifier numbers and averages of screw readings for comparison and stellar lines. The tape also contains the Zeeman shifts in microns for the individual stellar lines.

B. ZWAVL is a programme for determination of Zeeman Wavelength and Velocity from **GRINP** output tapes. The purpose of **ZWAVL** is to determine the observed stellar wavelength of the lines, calculate the average local radial velocity of the star from a set of known stellar lines, and finally to recalculate the laboratory wavelengths of all measured lines based on that velocity.

The computer first solves the equation $\lambda = a + b\,x$ for successive pairs of comparison lines and stores the various coefficients $\underline{a}$ and $\underline{b}$ in core memory. A separate line list (ID list) which identifies selected stellar lines is read into the computer along with the programme tape.

The computer differences the stellar and laboratory wavelengths and, using the first-order Doppler formula, calculates the average velocity of the star and the residuals for each line.

A second pass of the **GRINP** tape through the tape-reader allows the computer to calculate in serial fashion, using the average velocity just determined, the individual laboratory wavelengths of all remaining unknown lines which were measured.

ZWAVL has two parts, so that the best velocity can be used for the final line list of laboratory wavelengths. For example, an iterative process can be used with **ZWAVL.** In one case we measured a plate in which the first ID list contained only one line, the Balmer line Hγ. The velocity determined from that line was applied to all other lines and their laboratory wavelengths were determined. A second ID list could then be prepared which contained ten lines which could be identified with considerable certainty. The velocity was determined a second time using a ten-line ID list, and the velocity residuals were small enough (less than one kilometer per second) to assure that the ten lines were correctly identified. The wavelength list produced from the ten-line velocity was accurate enough ($\pm$ 0.01 Å) for the remaining thirty lines to be identified with a high degree of certainty. Finally, as a check, all forty lines were used to produce a third ID list, and a third average velocity was calculated for the plate. The velocity residuals from this solution were small enough on all lines to assure us that all forty lines were correctly identified.

ZWAVL produces lists and an output tape which contains the line identifier number, observed stellar wavelength, computed laboratory wavelength, and Zeeman shift for each line.

C. MAGFD. The final programme, **MAGFD,** computes the effective magnetic field for the star and its probable error. The programme takes as input a **ZWAVL** output tape which provides the wavelengths and measured Zeeman shifts for the lines, and a separate ID list which provides the individual z-values for the lines measured. The z-value of a line is the mean displacement of the group of components, to one side of centre, in terms of the displacement of the σ component of the normal Zeeman triplet.

The effective field is calculated from:

$$H_e = 52.7\, D \frac{\Sigma\, (z \cdot \triangle S_e)}{\Sigma\, (z)^2}$$

where D is the dispersion in Å/mm, $\triangle S_e$ is the individual Zeeman shift corrected to λ 4500 by multiplying by $(4500/\lambda)^2$, and z is the z-value described above. The equation is weighted by z according to the principle of least squares, since lines with large shifts statistically yield a better measure of the field strength.

The probable error is calculated by computing values of the field for each line and comparing them with the weighted mean value of H_e as determined above.

The output of **MAGFD** is a list on the teletype of the field and its probable error, the number of lines used to determine the field, and a list of z and $\triangle S_e$ values used in determination of the field.

IV. Summary and conclusion

The three programmes described above provide considerable speed and convenience in the processing of coudé Zeeman plates obtained on La Silla. If the ID lists for **ZWAVL** and **MAGFD** have been prepared in advance, the velocity, magnetic field, and probable error can be obtained within ten minutes after the plate has been measured using **GRINP**.

This paper was prepared to provide an example of the speed and convenience obtained by the use of a small computer used on-line with the Grant measuring machine.

Acknowledgements

The writer wishes to thank Frank Middelburg who wrote **GRINP** and **ZWAVL** and Luis Campusano B. who wrote **MAGFD**.

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PROGRAMMES FOR THE REDUCTION OF RADIAL VELOCITY MEASUREMENTS

A. Ardeberg and E. Maurice

Introduction

Measurements of radial velocities from spectra may nowadays be performed either by the modern method of superposition of line contours or by the more conventional setting of a reticule. For the choice of comparison and spectral lines for radial velocity determinations, the measurement procedure has to be taken into account, as line blends, etc., may have different effects in the contour superposition and the reticule setting methods. Basically, however, in both cases the same effects are measured.

For the measurements of radial velocities by line contour superposition, ESO has available in Chile a Grant machine. For radial velocity determinations by reticule setting, a Hilger and Watts microscope equipped with a Ferranti system can be used. For the measurements with these machines and for the reduction of the obtained data, programmes have been made. They are general enough to be applicable to most types of radial velocity measurements. They consist of two parts. One part is made for the measurements of the plates including some first-hand reductions. The other part is the actual reduction programme.

Measurements of the plates

The settings of the measuring machine, together with entered comments, identifiers and codes, define the input data. The measuring machine is connected to a teleprinter through which all data except the settings are entered.

Standard tables are used for the measurements of stellar, interstellar, nebular, and comparison lines. These tables contain selected lines to provide easy and consistent measurements. Tables are available for Cassegrain spectra (74 Å/mm) and for coudé spectra (12-20 Å/mm). Naturally, the selection of lines depends on the dispersion. Provision is made also for measurements of lines not included in the tables. For the stellar, interstellar, nebular and comparison lines a total of 500 lines may be tabulated. In addition to these lines, up to 500 non-tabulated lines may be used for a complete spectrum measurement.

However, for each individual table (stellar, interstellar, nebular and comparison) only up to 200 lines can be measured (if more than one mean value is formed for the same line, each mean value is regarded as a separate line).

Several sets of the same line can be measured separately, if any ambiguity or duplicity exists.

The measurement procedure is very simple. Identifiers and codes are given via the teleprinter. One or more measurements are made for every line desired.

For both measuring devices, the output is a punched paper tape. However, the information contained is not exactly the same. The Grant machine has an on-line connection with an HP 2100 computer, which makes possible direct calculation of mean values for every line measured. In this case the output tape contains one line of comments and the number of the stellar table used. The comments and the table number are entered by the operator. The tape also gives line identifiers and mean values of line measurements. The output tape from measurements made with the Hilger and Watts microscope contains, instead of mean values, the values of all the individual measurements. A quick run with the HP 2100 computer and a mean-values programme will convert the output tape from the Hilger and Watts machine into a tape exactly the same as that from the Grant machine.

Determination of radial velocities

The programme for the actual determination of radial velocities has been designed for an IBM 360/40 computer. In Santiago such a computer is available for ESO at the computer centre of the University of Chile. For convenience, the radial-velocity programme has been made for input from magnetic tape. The conversion of the measurements on the paper tapes to magnetic tape is made on the HP 2100 computer.

The input for the radial-velocity programme is thus the magnetic tape with the measurements and the punched cards with the line tables.

For each measured comparison line the programme calculates the difference between measured and tabulated position. It uses a least-square solution to fit a relation

$$X_m - X_0 = A_0 + A_1 X_m,$$

where X_m denotes measured and X_0 tabulated position. The programme eliminates all measured comparison lines with $|X_m - X_0|$ values deviating more than 40 μ from the fitted relation. In this way accidental errors in identification are avoided in the final fitting of a relation to the measurements of the comparison lines.

With the remaining comparison lines a least-squares fit is made of the relation

$$X_m - X_0 = B_0 + B_1 X_m + B_2 X_m^2 + B_3 X_m^3.$$

Also the standard deviation, σ, of the calculated differences $X_m - X_0$ with respect to the fitted relation is calculated. The programme then prints the constants B_0, B_1, B_2, and B_3, σ, and for every measured comparison line X_m — X_0 and X_m. Finally, eliminated lines, if any, are given. Also a plot is provided of $X_m - X_0$ versus X_m, including the fitted relation.

The fitted third-order relation for the comparison lines takes into account effects of dilatation, emulsion deformations, etc. The standard deviations provide an estimate of the quality of the plate and the measurements.

The differences between measured and tabulated positions are calculated for the measured stellar lines with tabulated values. They are then corrected by means of the relation found from the comparison lines. From the corrected position differences the corresponding radial velocites are calculated as

$$V = K\,(X_m^* - X_0^*)_{\text{corr.}}$$

Here V is the radial velocity and K is the velocity-position constant. K is given in the tables expressed in $\text{km.s}^{-1}.\mu^{-1}$. The asterisk refers to stellar lines.

Mean values and standard deviations are then calculated for the radial velocities of the stellar, the interstellar, and the nebular lines, respectively. A print-out is given of the values of V_i, $V_i - \bar{V}$, $\bar{V}$, σ^*, $\bar{\sigma}^*$, and N, where V_i are the radial velocities calculated for the individual lines, $\bar{V}$ the mean value, σ^* the standard deviation for a single stellar, interstellar or nebular line, $\bar{\sigma}^*$ the same quantity for the corresponding mean radial velocity, and N the number of stellar, interstellar or nebular lines taken into account.

For all individual stellar lines the residuals $V_i - \bar{V}$ are now compared to the corresponding values of σ^*. All lines with $| V_i - \bar{V} | > 2\sigma^*$ are eliminated

New mean values and standard deviations are calculated. Print-outs are given as before. The new residuals are compared to the new standard deviations, etc.

Finally, plots are given of V_i versus X_m^* for the stellar, interstellar, and nebular lines, respectively. These plots provide an easy means of checking for possible systematic effects.

For the measured spectral lines without tabulated values a different procedure is adopted. Using the measurements of the comparison lines and a least-squares solution, we fit a relation

$$\lambda = C_0 + C_1 X_m + C_2 X_m^2 + C_3 X_m^3.$$

The wavelengths, λ, are taken from the tables. The programme prints C_0, C_1, C_2, and C_3.

With the (λ ; X_m) relation obtained, measured positions of non-tabulated spectral lines are reduced to wavelengths. These wavelengths are printed together with the corresponding values of K. If a radial velocity has been calculated from tabulated stellar lines, the measured wavelengths are transformed into rest wavelengths, which are printed. A partial output may be obtained on magnetic tape.

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A DATA ACQUISITION PROGRAMME FOR PHOTOMETRIC MEASUREMENTS

A. Ardeberg and F. Middelburg

Introduction

An HP 2114B computer with 8 K words of memory in the dome of the ESO 1 m telescope on La Silla provides the possibility of rapid and reliable data acquisition, forming the basis of subsequent reduction programmes. At the same time, we can obtain on-line results by means of real-time reductions, which are necessarily much more restricted than those done in an off-line manner. The acquisition programme must allow an observing routine that is rapid, easy and flexible with no restrictions imposed on the observing procedure. Moreover, the observer must be free to choose at any moment the sequence of measurements. Thus highest priority has been given to an output that includes all data necessary for different types of reduction. The data output takes care of all kinds of photometry, with the number of filters ranging from one to twelve.

Once the results of a night are obtained, reduction can be made in several ways. We mention here reductions made with the help of a minicomputer and reductions with a large computer. If so desired, manual calculations may also be made.

The HP 2114B computer is linked by a data line to the 1 m telescope control computer. This link is used for transfer of coordinates and sidereal time from the telescope to the acquisition computer.

In this paper we present the programme used for data acquisition with the HP 2114B computer in connection with the ESO photometer (de Vries, 1966). We include a discussion concerning the on-line reduction programmes for UBV photometry. They provide results that are accurate enough to serve as preliminary information and at the same time suffice for evaluation of the photometric quality of the night.

Finally, we note that the programme is designed to give the observer the options of using either pulse-counting or DC-amplification techniques.

Measurement results

The output programme provides the data by means of a print-out on the teletype, another print-out on a high-speed printer, and a paper tape from a high-speed punch. At the same time, the intensity integrations are displayed on a counter for easy direct access during observing. Finally, a strip-chart recorder can be used, if so desired.

For a single integration, the output data for the teletype, the high-speed printer and the paper tape are the following:

an optional code	(two digits)
diaphragm code	(two digits)
integration time in seconds	(three digits)
sideral time for end of integration, expressed in hours and minutes	(four digits)
filter code	(two digits)
gain-step code	(two digits)
star-sky code	(one digit)
intensity value	(six digits)
decision	(one digit)

At the end of each integration these data are given automatically, except the decision, which has to be entered separately. If decision 0 is chosen, the decision is also given automatically at the end of each integration.

The option is also available for output of only mean values on the teletype print-out and on the paper tape. In this mode, the high-speed printer still gives single-integration results as above, whereas the teletype and the punch give the results for each series of integrations only. Output on the teletype and the paper tape is then made when measurement of object is terminated or when the filter, star-sky indication, gain-step, integration time, optional code or diagram is changed.

This ensures that data are not inadequately mixed. Furthermore, the output is made automatic and independent of intervention by the observer.

If only mean values are given on the teletype print-out and on the paper tape, a decision has to be made only after each series or the deletion of one or more integrations from a series.

Finally, mean values, as described, can be obtained by the teletype, while both the punch and the high-speed printer give the results of each integration. If the results of each integration are printed on the teletype, the integration time should be chosen at three seconds or more in order to avoid time-loss due to the print-out delay.

Each object is automatically given an incremental number, providing an easy reference for subsequent treatment of the data. All output is done under interrupt, which means that free access is available for an incoming integration, while the foregoing one is still under print-out.

The entered object identifier is printed on the teletype and on the high-speed printer and punched on the paper tape. The entered coordinates are printed on the teletype and punched on the paper tape. They are, however, omitted by the high-speed printer. It has also to be remembered that the high-speed printer gives only numeric characters and the minus character, whereas all other characters are represented by an asterisk.

At the end of each object-measurement a mean air-mass is given. The air-mass appears, however, only on the teletype print-out. It is calculated as for the reduction programmes (see below).

Apart from the direct results described above, a display is also given of the internal standard deviation in the mean value formed by the individual measurements so far made within the same series.

In Fig. 1 we give an example of a print-out made by the teleprinter during observing.

The programme

The first part of the programme takes care of the initiation phase, when the observer chooses his observing mode, enters the sidereal time and (possibly) enters the photometric parameters to be used for on-line reduction.

A second part of the programme is concerned with input of object identifiers, including right ascensions and declinations.

Finally, a third part of the programme takes care of the handling and output of the observational data. In this part also, on-line reductions may be performed and the results communicated.

Programme initiation

The programme is loaded using the basic binary loader. Pressing the run button on the computer starts the programme. After headings have been printed, the teleprinter will ask for the switch register to be set and for one line of comments to be typed.

By setting the switch register the observer can choose the observing mode that best fits his type of photometric work. The switches involved in the initiation phase are Nos. 1, 2, 4, 7 and 15.

Switches 1 and 2 are to be used for establishing the form of the data output.

As mentioned above, the high-speed printer and the counter display always give the result of every single integration. However, switches 1 and 2 provide options for the teletype as well as for the high-speed punch. If both switches are left untouched, the teletype and the punch will give mean values only (see "Measurement results"). Setting switch 1 means that all integrations are given on the teletype print-out, and setting switch 2 that all integrations are punched. For "regular" photometry it is recommended not to use all-values output on

```
**

HD 39591
5 31 17
-1 37
  1

MEASURE STAND. LIGHT SOONEST
MEASURE STAND. STAR SOONEST
72   5   1 0735   9 11 0       5 N=  5
72   5   1 0735   8 11 0   26407 N=  9
72   5   1 0736   9 11 0       4 N=  5
72   5   1 0737   1 11 1     131 N= 11
72   5   1 0737   2 11 1    1210 N= 10
72   5   1 0738   1 11 0   40137 N=  5
72   5   1 0739   2 11 0  414065 N=  7
72   5   1 0739   1 11 0   39755 N=  7
72   5   1 0740   2 11 1     860 N=  4
72   5   1 0740   1 11 1      80 N=  4

AIRMASS=  1.319


**

HD 32309
5 0 13
-20 5
  2

MEASURE STAND. STAR SOONEST
72   5   1 0742   1 11 1      58 N=  4
72   5   1 0742   2 11 1     525 N=  8
72   5   1 0743   1 11 0   45312 N=  6
72   5   1 0744   2 11 0  567718 N=  6
72   5   1 0744   1 11 0   44828 N=  6
72   5   1 0745   2 11 1     356 N=  4
72   5   1 0745   1 11 1      32 N=  5

AIRMASS=  1.267


**

HD 82121
9 27 34
-45 22
  3

TYPE STAND. MAG. V, B-V, U-B
7.620 -0.155 -0.63
72   5   1 0749   8 11 0   26299 N=  7
72   5   1 0749   9 11 0       3 N=  4
72   5   1 0750  12 11 0  343486 N=  6
72   5   1 0750  11 11 0   80443 N=  6
72   5   1 0751  10 11 0  107195 N=  8
72   5   1 0751  10 11 1     149 N=  5
72   5   1 0752  11 11 1     185 N=  3
72   5   1 0752  12 11 1     431 N=  4

AIRMASS=  1.103


**

HD 45629
6 26 48
-13 09
  4

72   5   1 0754   8 11 0   26100 N=  7
72   5   1 0754   9 11 0       4 N=  4
72   5   1 0755  12 11 0  507449 N=  4
72   5   1 0756  11 11 0  133488 N=  6
72   5   1 0756  10 11 0  110674 N=  8
72   5   1 0757  10 11 1     109 N=  4
72   5   1 0757  11 11 1     197 N=  7
72   5   1 0757  12 11 1     348 N=  5

AIRMASS=  1.114

V= 7.064  B-V= -.034  U-B= -.253
```

Fig. 1: Example of a print-out by the teleprinter during observing.

either the teletype or the punch. On the other hand, it would be natural to use it for observations of rapid variables. In the latter case, and if an integration time of less than three seconds is used, observing time can be gained by having the teletype give mean values only, whereas all values are punched.

Switch 4 is used to determine whether decision has to be given after each single integration, or whether decision has to be made only after each series of integrations (see "Measurement results"). If the switch is left untouched, decision has to be made only after each series of integrations. A series is terminated by pressing the stop button on the hand-set during the integration that is intended to be the last one. Setting switch 4 means that decision has to be made after each single integration. We recommend that the series-mode be used normally. The single-integration mode should generally be used when either only one integration for each filter, etc., is wanted, or when the photometric quality is doubtful.

When the DC amplification is used, the programme will normally check, before each integration, that the amplifier gain-setting is equal to the gain-setting of a previous measurement in either star or sky position for the same filter and object. This check option is normally very useful, especially in order to prevent star and sky for one or more filters from being measured in different gain-steps. Setting switch 7 will, however, disable this checking.

Switch 15, finally, determines if on-line UBV results should be calculated or not. If the switch is set, all complete UBV measurements will be followed by on-line magnitudes and colours.

It should be pointed out that the switches can always be reset after each object measurement. Thus, the observer may change his observing mood as desired during an observing night.

After the appropriate switches have been set, the observer may type one line of comments, including his name, the date, type of observation, etc. When the comment line has been terminated by carriage return-line feed, the high-speed punch will give first a tape leader and then punch the comment line so as to be directly readable (punching the geometrical forms of letters and numbers).

After this, the sidereal time is transferred from the telescope control computer to the HP 2114B computer. The teletype will print the time again as a check. If the observer notes that an erroneous time has been entered, he should set switch 9. The sidereal time will then be transferred again.

If switch 15 (on-line UBV reductions) has not been set, the teleprinter will print start and two asterisks, and the first object identifier can be entered. If switch 15 has been set — that is, if on-line UBV reductions are wanted — the teleprinter will ask for photometric parameters. A parameter tape is then entered via the photoreader. It should contain pre-selected values of extinction coefficients, colour transformation coefficients, and (in case DC amplification is used) gain-step factors. The teletype will then type start and two asterisks, and the first object identifier can be entered.

Object identifiers

Whenever the programme expects the input of an identifier for a following object, two asterisks are printed on the teleprinter.

The identifier may consist of up to 12 alphanumeric characters and should be typed on the teleprinter or entered via the photoreader. In any case the identifier will get printed on the teleprinter and punched on the high-speed punch. The high-speed printer prints the ten first numeric characters, whereas it replaces alpha characters and spaces by asterisks. All characters after the 12th will appear only on the teleprinter print-out. The identifier is terminated by a carriage return-line feed.

On the second line the right ascension and on the third line the declination will appear on the teleprinter print-out and on the punched tape. They are, however, omitted by the high-speed printer.

When the identifier has been entered, the object will be assigned an incremental number. This number appears on the print-outs of the teleprinter and the high-speed printer and on the punched tape. Immediately after this, the start and end lamps will light up on the hand-set as well as on the computer unit, informing the observer that he can start measuring. If at this point an error in the identifier is noticed, pressing the end button will bring the programme back to typing two asterisks on the teleprinter, after which the correct identifier can be entered.

After the incremental number has been printed and the start and end lights have gone on, one line of comments may be typed. These comments will appear only on the teleprinter print-out.

If the observer wants to check the sidereal time, he can do so before entering an identifier (when the two asterisks have been printed). Setting switch 8 will then cause the sidereal time to be continuously printed out until the switch is reset. If switch 9 is then set, the internal sidereal time is reset and can be entered again.

Observations

The first integration for an object can start immediately after the incremental number has been printed on the teleprinter and the start and end lamps have lighted up, or (possibly) after one line of comments has been typed following the incremental number.

We describe first the procedure to be followed if switch 4 has not been set—that is, the series-mode. In this mode the programme will continue making integrations until the stop button is pressed.

When the object has been centred, and diaphragm, integration time, filter, star-sky indicator, and (in case of DC amplification) gain-step selected, the measurement is initiated by pressing the start button. We point out that all commands (start, stop, decision, end, and star-sky indication) can be made from the computer unit as well as from the hand-set. The normal observing procedure should be that the observer stays at the photometer, whence he can control everything. The night assistant will normally enter object identifiers and coordinates.

When the start button is pressed, the stop light goes on, and the counter starts the first integration. The programme will cause the integrations to continue until the stop button is pressed. After each integration the obtained intensity value will be displayed by the counter. This value then remains, while next integration goes on, at the end of which the new intensity value will be displayed. The dead time between consecutive integrations is about 0.3 seconds.

After two integrations with the same filter, diaphragm, integration time, and (in case of DC amplification) gain-step, and with the star-sky indicator in position star, a mean error display will be given, provided a previous sky measurement has been made with the same filter and, for DC, gain-setting. After each new integration with the same settings the displayed error will be up-dated.

The error given is S, where

$$S = \sqrt{\frac{\sum_{i=1}^{N} (X_i - \overline{X})^2}{N\,(N-1)}}$$

Here $X_i = X - X_0$

X = star intensity normalized to one second integration time.

X_0 = sky intensity normalized to one second integration time and to the same diaphragm as was used for the measurement of the star.

$$\overline{X} = N^{-1} \sum_{i=1}^{N} X_i$$

N = number of star measurements so far made.

The sky intensity used for calculation of the mean error is the mean value of the previous series of sky measurements made with the same filter and (in case of DC amplification) the same gain-setting. These sky intensity values for all filters and, for DC work, gain-settings so far used are stored in core memory. For each filter (and gain-steps) the stored sky intensity values are continuously replaced when new sky measurements are made. Thus a set of up-dated sky intensity values is maintained which can be referred to by the programme when an error calculation has to be made. If no corresponding sky measurement is available, no error will be given.

We stress the fact that a preceding corresponding sky value is always used for the error calculation. This means firstly that, so long as no corresponding sky measurement has been made during the night, no error will be given. Secondly, as soon as at least one corresponding sky measurement has been made, error calculation will be made. Thirdly, if sky measurements are not made for every star, it is essential to make new sky measurements as soon as the sky brightness changes, in order to avoid incorrect results. To obtain the error calculation it is, however, by no means necessary to measure the sky for every object.

For measurements of the standard light source no error is calculated.

The mean error is displayed by means of the switch register provided with an extra transparent plate having numbers clearly visible from the telescope, when lit up by the corresponding switch. The number displayed is an integer S, where

$$\bar{S} - 0.5 < S \leq \bar{S} + 0.5, \; 0 \leq \bar{S} \leq 15.$$

If $S > 15.5$, switches 14 and 15 will both light up.

The error display is intended as a help during the observations only; no mean error appears on either the listings or the punched tape. Good advantage can, however, be taken of the error display for judging the number of measurements needed to achieve a certain accuracy. It is also valuable for evalution of the photometric quality.

By setting switch 0 all stored sky values are deleted.

Finally, it should be noted that an erroneous setting of the star-sky indicator on star when sky is actually measured will make the error display spurious. If a rapidly-increasing error is noted, the star-sky indicator should be checked.

When the desired mean error has been reached or the desired number of integrations made, the stop button is pressed; the integration under way at that moment will be finished. Then the programme stops the integration. The decision light goes on and the decision selector should be set to the appropriate number. The decision button is then pressed.

The decision selector has six positions: 0, 1, 2, 3, 4 and 5. The consequences of these decisions are the following:

1 = All integrations in the last integration sequence are accepted.

2 = All integrations in the last integration sequence are accepted, except the last one, which is rejected. The display of the mean error is returned to the value it had before the last integration.

3 = All integrations in the last integration sequence are deleted. In the case of DC amplification, the stored gain-setting is removed.

4 = All measurements of the present object are deleted. If any integration values have been printed and punched, a delete message will be given on the teletype print-out and on the punched tape. In this case the identifier of the object has to be re-entered.

0 = The same as decision 1, but the decision will be made automatically at the end of the last integration in every integration sequence.
With this decision the decision lamps will never be illuminated.

5 = Not used for the present data acquisition programme.

Normally decision 1 is used, which means that no decision selection has to be made. Only in exceptional cases has one of the decisions 2-4 to be used.

Decision 2 should be chosen if, for instance, it is established that the object approached the diaphragm edge during an integration terminated by means of the stop button. If it is not certain at what time during the integration sequence the star started to approach the edge, decision 3 should be taken. Decision 4 is appropriate if it is found that the measured object is not the correct one and integration values have already been printed and punched. Decision 0 should normally be used only for test integrations.

If the start or end buttons are pressed while the decision lamp is illuminated, this lamp will start flashing. Pressing the decision button will terminate the flashing and enter the decision.

When the decision has been entered, the start and end lamps will light up. The observer can now either go on measuring with the same diaphragm, integration time, filter, star-sky indicator, and gain-step, or he can change any of these observing parameters and then go on measuring. In the first case, with decision 1, everything will continue as if no intermediate decision had been made. With decision 2 or 3 the measurement sequence will continue to build up, omitting the last integration or the whole previous series of integrations. Decision 4 means that the identifier has to be re-entered.

If the observer changes any of the quantities listed above (diaphragm, etc.), a mean value will be given of the previous intensity measurements. This mean value is printed by the teletype. If the mean-values mode is chosen for the punch (switch 2 untouched), this mean value will also come out on the paper tape.

While the mean value is being printed (and punched), the next integration starts. The process described above may then be repeated for all desired combinations of stars as well as of sky.

When the observer has finished with the object, he presses the end button. Then, the final mean value will appear.

Directly after that, the teletype gives the air-mass at which the object was measured. Finally, on-line results may be printed by the teletype.

We recall that different filters, etc., may be used for stars and sky in any sequence and as often as desired.

If switch 4 has been set, the observer has to make a decision for every single integration. Thus, the decision light will come on after every integration. As in the series-mode, the entry of a decision will cause the start and end lamps to light up. Then the observer has the choice of continuing to measure with the same set of parameters, of changing it or of ending with the object. Error display is given as for the series-mode.

At the end of an observing night, the word END should be typed, followed by carrier return and line feed. An end code will then be punched on the paper tape, a halt instruction be given in the power failure interrupt cell and the computer halted.

A flow chart of the normal observing procedure is given in Fig. 2.

Air-mass

The air-mass communicated at the end of the observations of an object is calculated as X, where

$$X = \sec z - 0.00182\,(\sec z - 1) - 0.00288\,(\sec z - 1)^2 - 0.00081\,(\sec z - 1)^3$$

Here $\sec z = \left(\sin\varphi \sin\delta + \cos\varphi \cos\delta \cos\,(t - \alpha)\right)^{-1}$,

Where
φ = latitude of observatory
δ = declination of object
t = sidereal time for measurement
α = right ascension of object

We recall that the air-mass is communicated only by the teletype.

Gain-checking

If DC amplification is used, gain-checking is done provided switch 7 is not set. Then the programme checks before each integration that the amplifier gain-setting is equal to that of previous measurement(s) with the same filter. This check is made for all measurements of stars as well as of sky. In addition, the gain-setting for the standard light source is checked against the gain-setting for the dark current and vice versa.

If a difference in gain-setting is encountered, the switch register will start flashing, and a message appears on the teletype. Moreover, no integration can be started. The decision lamps will be on; the programme expecting the gain-setting error to be corrected via the decision selector and button.

One of two decisions must then be made: If the actual gain-setting (or filter-setting) is found erroneous, decision 1 should be given. If the previous gain-setting is found erroneous or less favourable, decision 2 should be given.

In both cases, pressing the decision button will cause the start and end lights to go on. In the case of decision 1, the observer can correct his gain (or filter)

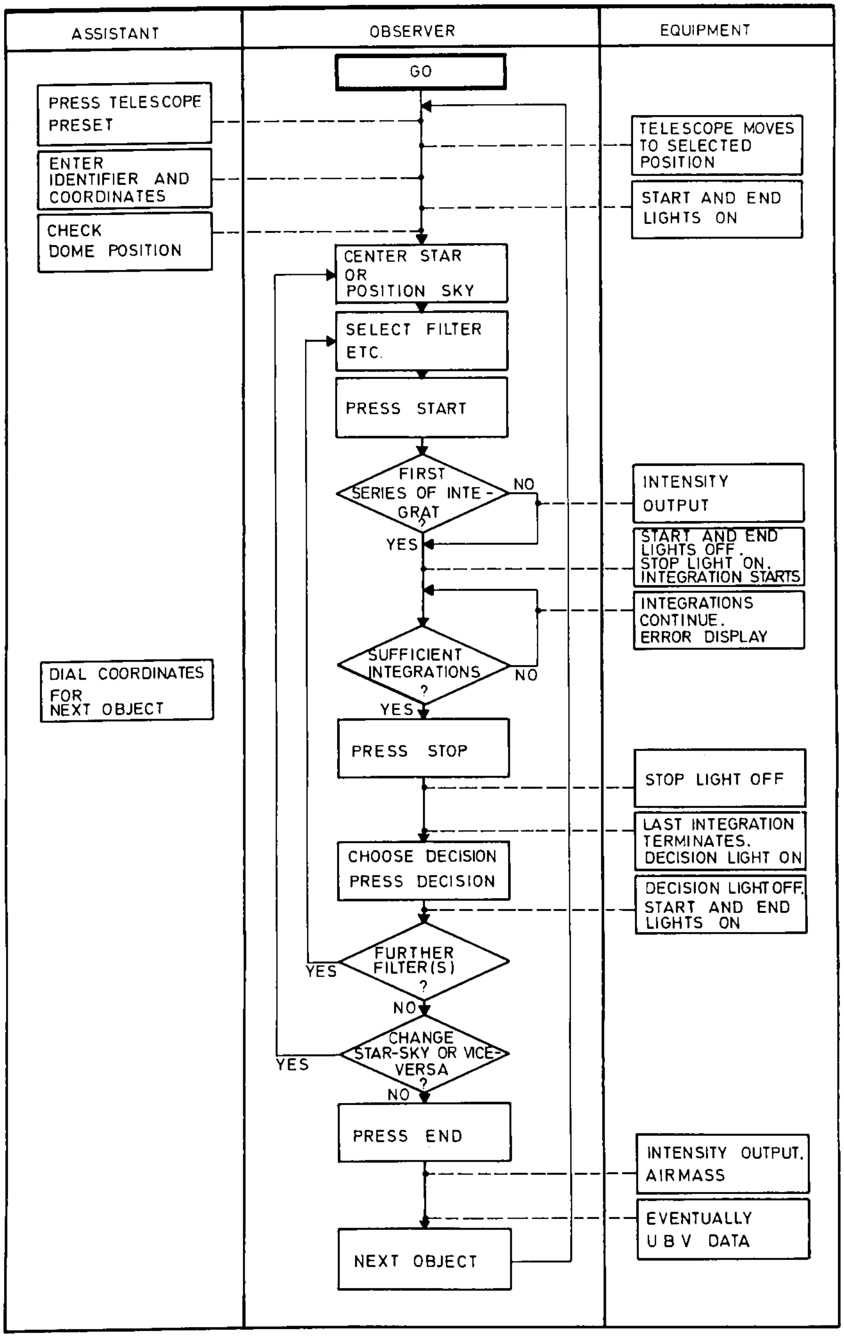

Fig. 2: Normal observing procedure for series-mode measurements.

setting and go on observing. In the case of decision 2, the gain-checking is suppressed. Moreover, in this case the observing can continue without interruption.

It should be mentioned that decision 0, 4 and 5 have the same effect as decision 1.

We point out that there is no connection between the decision codes that have to be used after a gain-setting error and the decision codes to be entered after an integration or a series of integrations. Finally, we recall that setting of switch 7 suppresses all gain-checking.

Power failure

During the observations it may sometimes happen that the main power declines for a moment. If this occurs, the computer switches off and halts. As soon as the power comes on again, a routine is executed which brings back the programme to a point where the observing can continue safely. The teleprinter then gives a warning to reset the counter, to switch on the DC on the punch and to re-enter the sidereal time.

As the power might have failed while the punch was in operation, unpredictable errors may exist on the paper tape. For that reason the programme always gives rub-out, carrier-return and line-feed characters when the power comes back.

If a power failure occurs in the initiation phase or when an identifier is being entered, the programme will return to the beginning of that phase. The observer can then re-enter the data.

Finally, the power failure may occur while an object is being measured. In this case, an object-delete code is punched on the paper tape and a "star-delete" message appears on the teletype print-out. The programme will then return, printing two asterisks, and the observer can re-enter the object identifier (and the coordinates) and start measuring the object again.

On-line UBV reductions

If the observer is using the UBV system, he has the possibility of obtaining on-line reductions of the measurements.

The on-line reduction programme for UBV measurements is constructed so that for any object filters other than the UBV ones can also be used during the same object measurements for which on-line magnitudes and colours in the UBV system are calculated. If, for instance, UBVHβ photometry is done, all measurements will be accepted by the teletype as well as the paper tape punch and the high-speed printer, whereas on-line UBV results will be communicated by the teletype only. The on-line UBV reduction programme, as well as the data acquisition programme, accepts measurements through all different filters in any sequence and as often as desired.

For practical reasons the on-line reduction programme has been kept fairly limited. Pre-selected values of extinction coefficients and instrumental constants are used. Experience has shown that this does not impose any serious limitation if well up-dated values are taken for the instrumental constants.

The atmospheric and instrumental coefficients and constants, which have to be entered, are first- and second-order extinction coefficients, colour-equation constants, and (if DC amplification is used) gain-step conversion factors.

A simple choice for the first-order extinction coefficients are the general or seasonal mean values. With the excellent atmospheric conditions prevailing on La Silla these mean values will always give a very good approximation. Mean values calculated for some observing nights directly preceding the night in question might, of course, provide an adequate alternative.

For the second-order extinction coefficients, standard values can always be used.

The constants for the conversion of magnitudes and colours into the standard UBV system should always be the values obtained in directly preceding observing runs. However, even with up-dated values of those constants, great care has to be taken if filter(s) and/or photomultiplier have been changed and if one or more of the mirror surfaces have been recently aluminized.

If DC amplification is used, up-dated gain-step conversion factors must always be used. Any resistor change should be followed by a calibration.

The zero-points of the relations connecting the instrumental magnitudes and colours to the standard system are defined by means of measurement of a single selected star. This approach has been taken to achieve simplicity. With the zero-point standard star properly selected, the zero-points obtained should be correct within about the measuring accuracy of a normal programme star.

Further, each on-line magnitude for V is corrected to the nearest previous measurement of the standard light source. In this way any drift in equipment sensitivity is compensated. If an atmospheric shift of the zero-points should occur, a new zero-point standard star (possibly the same as before) can be measured and the zero-points reset.

It should be pointed out that the setting of the zero-points does not cause any time loss, as the intensities for the zero-point standard star will be given as for all the other stars.

On-line UBV reductions may be obtained during the whole or part of an observing night. The on-line reductions can be initiated and terminated for any object measurement.

When the observer wants on-line UBV reductions he should:

— set switch 15 when the teleprinter gives two asterisks,

— set switch 10 if the star to be measured is also the selected zero-point standard.

In any case the teletype will ask for the photometric parameters to be loaded via the photoreader. When this is done, identifier and coordinates are entered as normal.

If switch 10 has been set, the teletype will ask for the V magnitude and (B-V) and (U-B) colour indices to be typed. Then the zero-point standard star can be measured. A measurement of the standard light source and the dark current has to be included in this measurement. Starting with the following object, on-line UBV data will then be communicated by the teletype in all adequate cases. The on-line reductions will continue for the rest of the observing night without any intervention from the observer.

If the first star to be measured is not the selected zero-point standard, only switch 15 is set. The teletype will then at the beginning of every object measurement ask that the standard light source and the zero-point standard star be measured. If the standard light source (together with dark current) is measured, the teletype will from then on ask for measurement of the zero-point standard only. When the zero-point standard star is to be measured, switch 10 has to be set after the teletype has given the corresponding asterisks. The standard light source (and the dark current) has to be measured at the latest during this object measurement. However, the messages concerning zero-point standard star and standard light source may be ignored.

Once standard light source and zero-point standard have been measured, UBV data will be calculated and communicated in all adequate cases. Switch 10 will be reset automatically as soon as the zero-point standard star has been measured.

On-line UBV reductions will not be performed if one or more of the UBV filters are missing for star or sky. Nor will they be performed if the diaphragm has been changed during measurement. (It may, however, be changed as desired from object to object.)

If no on-line UBV data appear after a UBV measurement for which on-line reduction is expected, the cause is, normally, that one of the filters is missing for star or sky. If only a sky measurement is missing, sky interpolation can then be performed in a final reduction, and there is no absolute need to remeasure the star.

With DC amplification, the gain-steps for the three filters have to be equal for star and sky. This is checked by the programme.

The parameter (paper) tape should consist of three records, which may be punched in free field. The first record should contain six coefficients for first- and second-order extinction coefficients. The second record should contain seven gain-step conversion factors, and the third record nine constants giving slopes and zero-points for the colour relations. The zero-points are intended for compatibility only, as the programme will anyhow set its own constants by means of the measurement of the zero-point standard star. Provision is made for the eventuality that the (U-B) colour relation turns out to be non-linear.

Measurements are reduced for first- and second-order extinction according to:

$$\begin{aligned} V_0 &= V_c - X\left(C_1(V) + C_2(V) \times (B\text{-}V)_c\right), \\ (B\text{-}V)_0 &= (B\text{-}V)_c - X\left(C_1(B\text{-}V) + C_2(B\text{-}V) \times (B\text{-}V)_c\right), \\ (U\text{-}B)_0 &= (U\text{-}B)_c - X\left(C_1(U\text{-}B) + C_2(U\text{-}B) \times (U\text{-}B)_c\right), \end{aligned}$$

wh›.e the index c denotes calculated magnitudes and colours. C_1 and C_2 are the coefficients for first- and second-order extinction, respectively.

Transformation to the standard magnitude and colour system is made according to:

$$\begin{aligned} V_{std} &= V_0 + A \times (B\text{-}V)_0 + C \\ (B\text{-}V)_{std} &= (B\text{-}V)_0 + D \times (B\text{-}V)_0 + E \\ (U\text{-}B)_{std} &= (U\text{-}B)_0 + F \times (U\text{-}B)_0 + G \text{ for } (U\text{-}B)_0 \leq H \\ (U\text{-}B)_{std} &= (U\text{-}B)_0 + I \times (U\text{-}B)_0 + K \text{ for } (U\text{-}B)_0 > H \end{aligned}$$

Normally, the two (U-B) colour relations are found to be identical.

Zero-point correction follows as:

$$\begin{aligned} V^1 &= V_{std} + V_z^0 - V_z \\ (B\text{-}V) &= (B\text{-}V)_{std} + (B\text{-}V)_z^0 - (B\text{-}V)_z \\ (U\text{-}B) &= (U\text{-}B)_{std} + (U\text{-}B)_z^0 - (U\text{-}B)_z \end{aligned}$$

Where V_z^0, $(B\text{-}V)^0$, and $(U\text{-}B)_z^0$ are the loaded standard magnitude and colour indices for the zero-point standard star, whereas the V_z, $(B\text{-}V)_z$, and $(U\text{-}B)_z$ denote the measured magnitude and colours for this star, reduced for extinction and colour equation.

Finally, the V magnitudes are corrected for varying equipment sensitivity according to:

$$V = V^1 - M + M_0.$$

Here M denotes the magnitude for the standard light source minus dark current taken for the nearest previous standard light source measurement. M_0 denotes the standard light source magnitude for the measurement of the zero-point standard star.

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PRISMATIC SPECTROGRAMS OF SOUTHERN MK STARS

Alfonso R. Condal, H. John Wood, Hugo Moreno and
members of the Spectrographic Seminar of the University of Chile 1971*

I. Introduction

In this paper we present several series of spectrograms of southern stars with MK spectral types which were obtained at Cerro Tololo Inter-American Observatory (CTIO). The spectrograms were obtained by the junior authors as part of a seminar in spectroscopy given in the ESO Headquarters in Santiago by Dr. H. J. Wood. The purpose of the paper is to provide, for students and researchers, examples of the MK standards taken with a small telescope and fast prismatic spectrograph. Spectrograms of 38 stars are presented. The plate file of more than 75 stars is available at the Cerro Calán Observatory for use on future research projects.

The plates are presented here in a format enabling the individual spectrograms to be cut out and intercompared.

II. The observations

Half of the plates presented here were obtained by the junior authors on December 14-17, 1971, U. T. A similar set of MK standards which helped fill in gaps in the plate file was provided by Prof. H. Moreno. The Moreno plates were obtained on October 25-28, 1967, with the same instrument and they appear with slightly greater widening than the present plates in our figures.

The spectrograph was designed and built by Professor W. A. Hiltner specially for spectral classification work. With a refractive collimator and fast camera, the instrument gives satisfactory classification spectrograms on IIa-O plates with 20 minutes exposure for 6th magnitude A-type stars. The telescope used was the number one 16-inch reflector and the widening on the plate is 0.9 mm. The spectrograms have 120 Å/mm reciprocal dispersion on the plate at Hγ.

III. Conclusion

In the figures we have included line-identification of some temperature- and luminosity-sensitive lines. However, we urge the reader to compare the present spectrograms with those of the MKK atlas (Morgan, Keenan, and Kellman, 1943)

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Table 1: Spectrophotometric data for stars of this paper

HR	Name	m_v	B-V	Sp	b-y	m_1	c_1	β	Ref.
99	α Phe	2^m39	$+ 1^m08$	K0 III					
100	κ Phe	3.93	+ 0.17	A7 Vn	$+0^m100$	0^m192	$+0^m915$	2^m842	CBG 1
322	β Phe	3.30	+ 0.89	G8 III					
509	52 τ Cet	3.50	+ 0.72	G8 Vp	+ 0.445	0.250	+ 0.247		CB
591	α Hyi	2.86	+ 0.29	FO V	+ 0.175	0.193	+ 0.869	2.771	CBG 1
804	86 γ Cet	3.47	+ 0.09	A2 V					
811	89 π Cet	4.23	— 0.13	B7 V	— 0.048	0.096	+ 0.607	2.719	CBG 1
1083	κ Ret	4.70	+ 0.39	F5 V	+ 0.262	0.158	+ 0.501	2.667	CBG 1
1084	18 ε Eri	3.73	+ 0.89	K2 V					
1325	40 o² Eri	4.42	+ 0.82	K1 V					
1393	43 Eri	3.96	+ 1.49	M1 III					
1674	ζ Dor	4.71	+ 0.53	F8 V	+ 0.335	0.167	+ 0.338	2.618	CBG 1
1713	19 β Ori	0.08	— 0.03	B8 Ia					
1735	20 τ Ori	3.59	— 0.12	B5 III	— 0.041	0.111	+ 0.573	2.687	CBG 3
1790	24 γ Ori	1.64	— 0.23	B2 III	— 0.091	0.076	+ 0.111	2.614	CBG 3
1865	11 α Lep	2.59	+ 0.22	F0 Ib	+ 0.139	0.148	+ 1.504	2.730	CBG 1
1899	44 ι Ori	2.77	— 0.25	09 III	— 0.094	0.054	— 0.103	2.587	CBG 3
1903	46 ε Ori	1.70	— 0.19	B0 Ia	— 0.032	0.026	— 0.090	2.557	CBG 3
1948	50 ζ Ori	2.05	—	09.5Ib	— 0.061	0.033	— 0.121	2.570	CBG 3
1996	μ Col	5.16	— 0.29	09.5 V	— 0.116	0.058	— 0.110	2.598	CBG 2
2874	HD 59612	4.85	+ 0.23	A5 Ib	+ 0.171	0.082	+ 1.530	2.692	CBG 1
3064	9 Pup	5.16	+ 0.60	G1 V					
3192	16 Pup	4.40	— 0.17	B5 V	— 0.069	0.103	0.393	2.684	CBG 1
3498	HD 75311	4.63	—	B2 Vne	— 0.061	0.085	Var.	2.601	CBG 1
3634	λ Vel	2.30	+ 1.70	K5 Ib					
3684	HD 79940	4.62	+ 0.46	F5 III	+ 0.291	0.166	0.671	2.668	CBG 1
3862	HD 84117	4.93	+ 0.53	G0 V	+ 0.336	0.160	0.384	2.609	S
3975	30 η Leo	3.48	— 0.02	A0 Ib	+ 0.030	0.068	0.966	2.652	CEA
4520	λ Mus	3.61	+ 0.16	A7 II—III	+ 0.086	0.179	1.073	2.856	CBG 1
7557	53 α Aql	0.77	+ 0.22	A7 V	+ 0.137	0.162	0.853	2.828	BS
7747	5 α¹ Cap	4.22	+ 1.06	G3 Ib	+ 0.571	0.327	0.389	2.617	CBG 1
7950	2 ε Aqr	3.77	+ 0.01	A1 V	+ 0.002	0.144	1.192	2.882	CEA
8232	22 β Aqr	2.89	+ 0.84	G0 Ib	+ 0.519	0.424	0.440	2.624	BS
8308	8 ε Peg	2.42	+ 1.56	K2 Ib					
8353	γ Gru	3.00	— 0.12	B8 III	— 0.048	0.104	0.734	2.748	CBG 1
8634	42 ζ Peg	3.47	— 0.10	B8 V	— 0.035	0.114	0.867		CB

and *An Atlas of Low Dispersion Grating Stellar Spectra,* by Abt, Meinel, Morgan and Tapscott (1968) for details of the classification techniques.

Table 1 lists various spectrophotometric data for the stars which appear in the figures. The magnitudes, spectral types, and B-V colours are from the *Catalogue of Bright Stars* (Hoffleit, 1964). The 4-colour and Hβ photometry, when available, is from the following sources: The punched card version of the bright star catalogue (BS), "Standard Stars for u v b y Photometry" Crawford

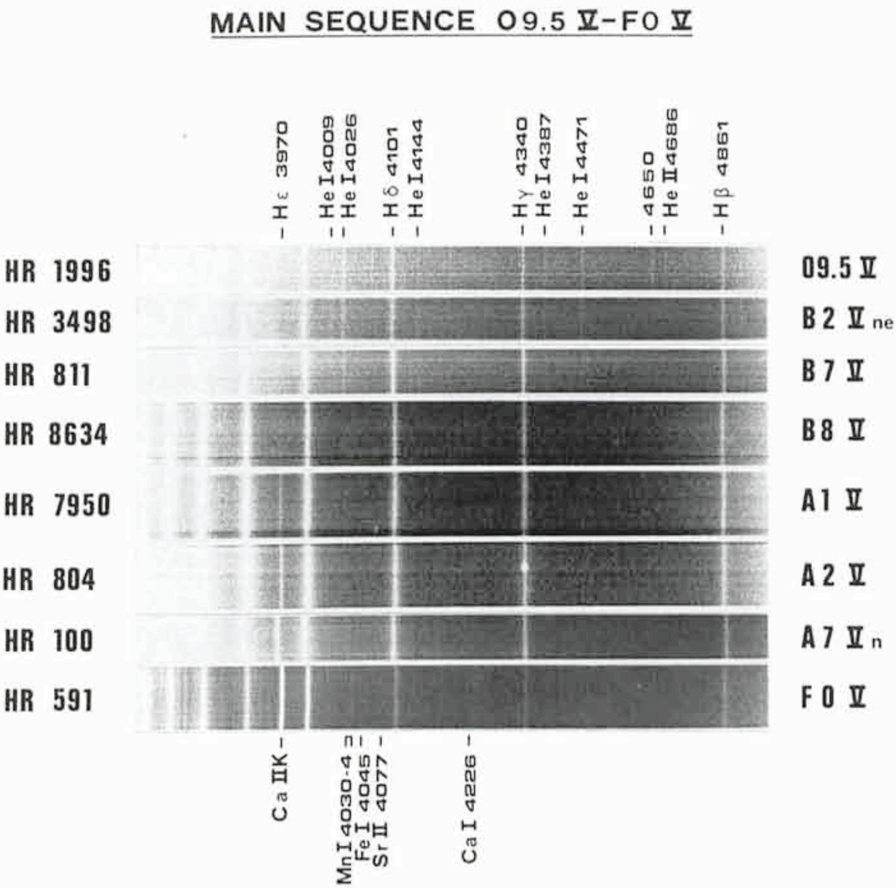

Fig. 1: The important temperature-sensitive features are marked. Notice that Mg II 4481 appears close to He I 4471 at B7 and that both lines have nearly equal strength.

and Barnes, 1970 (CB); "Four-Color and Hβ Photometry for the Brighter AO Type Stars", Crawford *et al.*, 1971 (CEA); "Four-Color and Hβ Photometry for Bright Stars in the Southern Hemisphere", Crawford, Barnes, and Golson, 1970 (CBG1); "Four-Color and Hβ Photometry for Bright B-Type Stars in the Southern Hemisphere", Crawford, Barnes and Golson, 1971a (CBG2); "Four-Color, Hβ and *UBV* Photometry for Bright B-Type Stars in the Northern

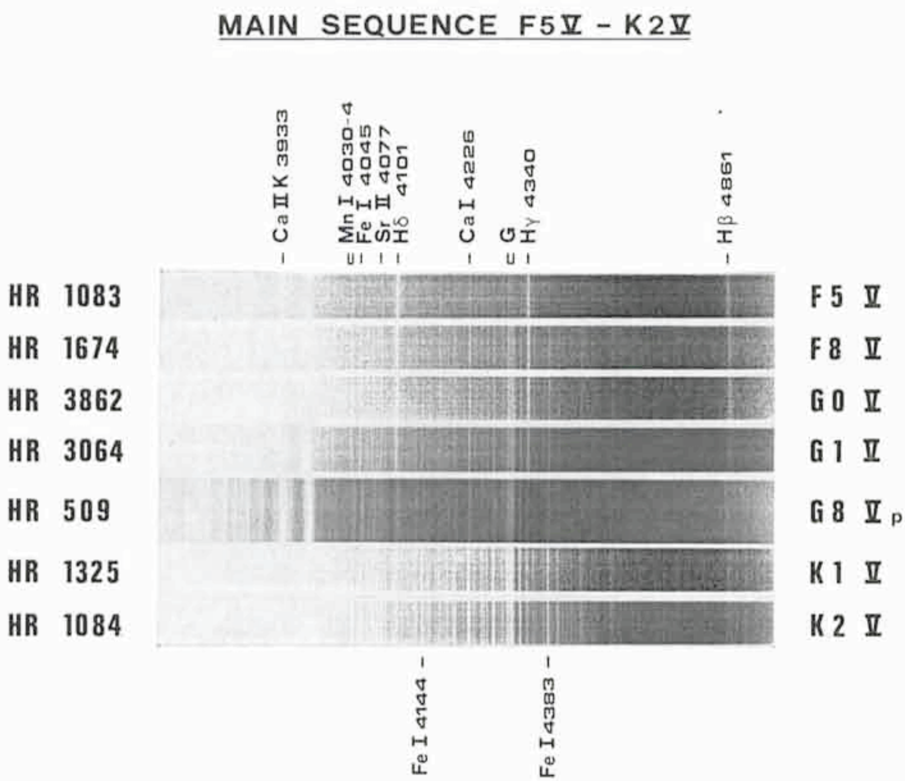

Fig. 2.

Hemisphere", Crawford, Barnes and Golson, 1971 b (CBG3); "Four-colour and Hβ photometry of some bright southern stars", Stokes, 1972 (S).

We are indebted to Prof. B. E. Westerlund for consultations and to Messrs. W. Eckert and H. Vogel for making the prints. Thanks are due to Dr. John Graham and the CTIO staff for the award of telescope time for this student project.

GIANTS O9III - MI III

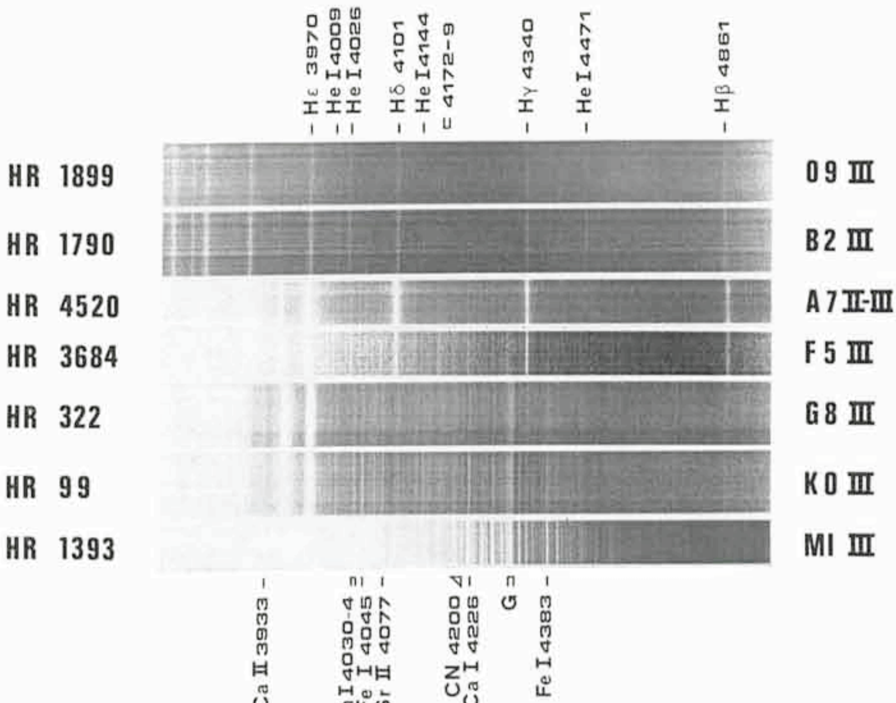

Fig. 3: The hydrogen and helium lines are systematically weaker than in the dwarfs. The CN 4200 band, Sr II 4077 and a blend at 4172-9 are luminosity-sensitive in stars later than A7.

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SUPERGIANTS O9.5Ib–K5Ib

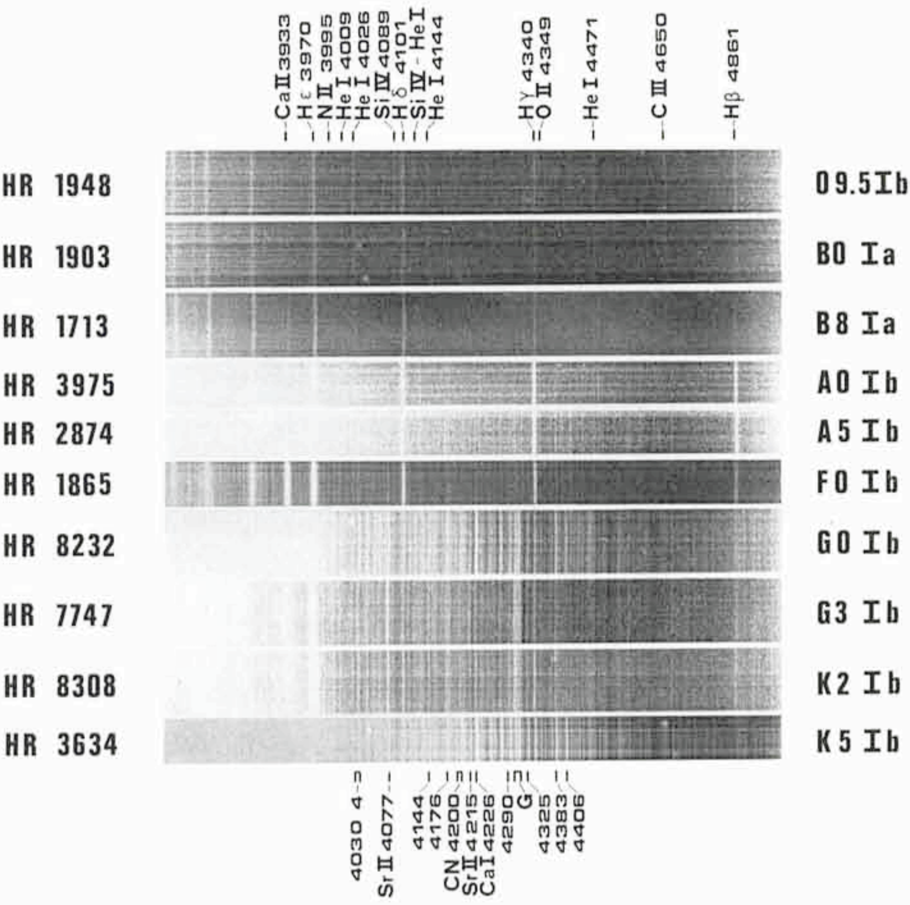

Fig. 4.

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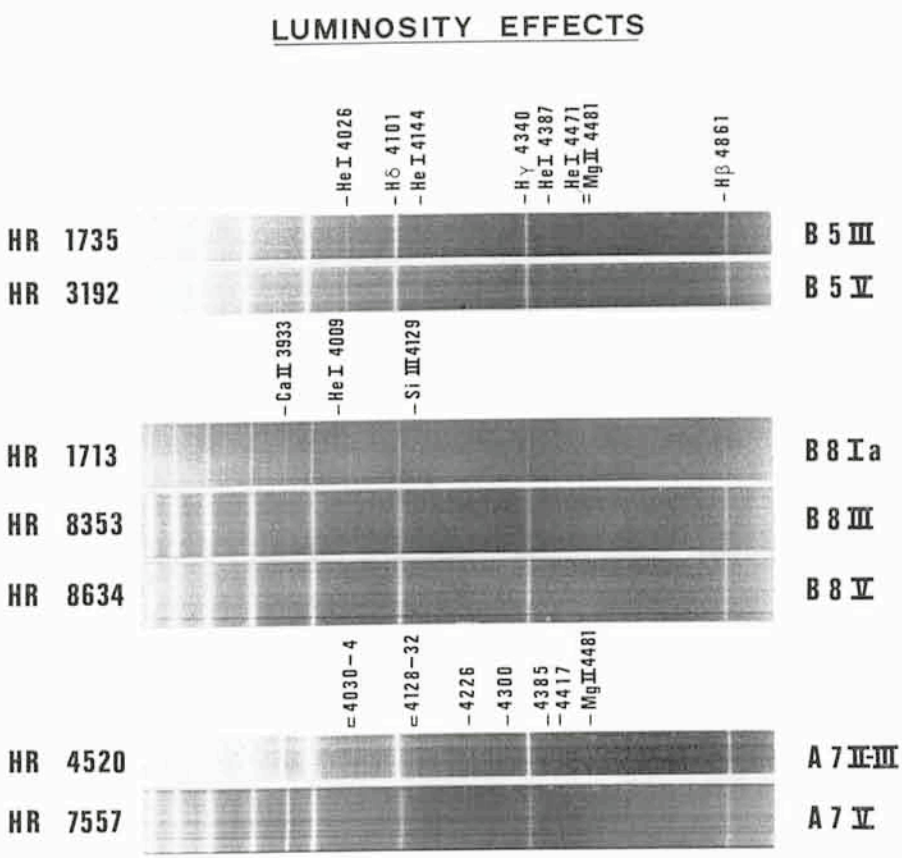

Fig. 5: The ratio 4471 : 4481 varies with absolute magnitude at B5.

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* Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation, Washington, D. C.

NOTICE

With this issue the European Southern Observatory terminates the publication of the ESO Bulletins. Articles of general interest will in future be published in the regular journals.

To avoid confusion we also note that the series "Communications of the European Southern Observatory", consisting of reprints from the period 1962-69, has been discontinued following Communication No. 8.

L. Woltjer
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of ESO Bulletins Nos. 1-12

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* Addresses held during the Inauguration of the European Southern Observatory at La Silla on March 25, 1969.

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