



EUROPEAN SOUTHERN OBSERVATORY

OPERATING MANUAL

No. 2 – March 1989

THE ESO CASSEGRAIN ECHELLE SPECTROGRAPH (CASPEC)

The ESO Cassegrain Echelle Spectrograph (Caspec)

**L. Pasquini
S. D'Odorico**

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Chapter 1

Introduction

This manual is a revision of the first version of the CASPEC manual written by D'Odorico and Tanné in 1984.

With this manual we would like to provide CASPEC observers with a guide for preparing and performing in the best way their observations. A detailed description of the instrument design and installation is not given here but can be found in references [1] and [2]. We invite the users to read this manual carefully and to familiarize themselves with the instrument and the control software.

We strongly encourage users to make any comments and suggestions concerning this manual in order that we may refine future versions. Please do this by firstly writing on a copy of this manual which you will find in the control room of the telescope and secondly in your observing report to be completed at the end of your observing mission to La Silla.

Chapter 2

Instrument configuration

2.1 The Standard configuration

The ESO Cassegrain Echelle Spectrograph (CASPEC) is used at the Cassegrain focus of the 3.6 m telescope. The optical layout is shown in Fig. 2.1. In the standard configuration the light is dispersed by the 31.6 lines/mm echelle grating and is cross dispersed by a mosaic of two 300 lines/mm gratings that separates the echelle orders and provides a convenient two dimensional format. The light is focused onto the detector by the so-called short camera ($F = 291$ mm, $f/1.6$). The detector in use at the time of writing (March 1989) is ESO CCD # 8. The specifications are given in Appendix A. With this configuration 1 mm on the CCD corresponds to $37''.3$ on the sky in the direction of the dispersion and to $24''$ in the perpendicular direction. A typical CASPEC spectrum is shown in Fig. 2.2.

2.2 The 52 lines/mm echelle grating

The separation between the orders is quite small with the 31.6 lines/mm echelle grating when used in the blue spectral region. An alternative echelle grating with 52 lines/mm is available, which can be used for observations in the blue and/or if a larger inter-order spacing is necessary. The inter-order space with this echelle is about 1.6 times larger than with the 31.6 lines/mm echelle (see section 3.1). However, with the present detector geometry, the orders only overlap (i.e. give continuous spectral coverage) for wavelengths shorter than about $\lambda = 5000$ Å. Notice also that the 52 line/mm grating is less efficient than the 31.6 lines/mm grating, so it should be used only if more separation between orders is needed (e.g. for observations of extended sources). Figure 2.3 shows the efficiency curves of the two echelle gratings available for CASPEC.

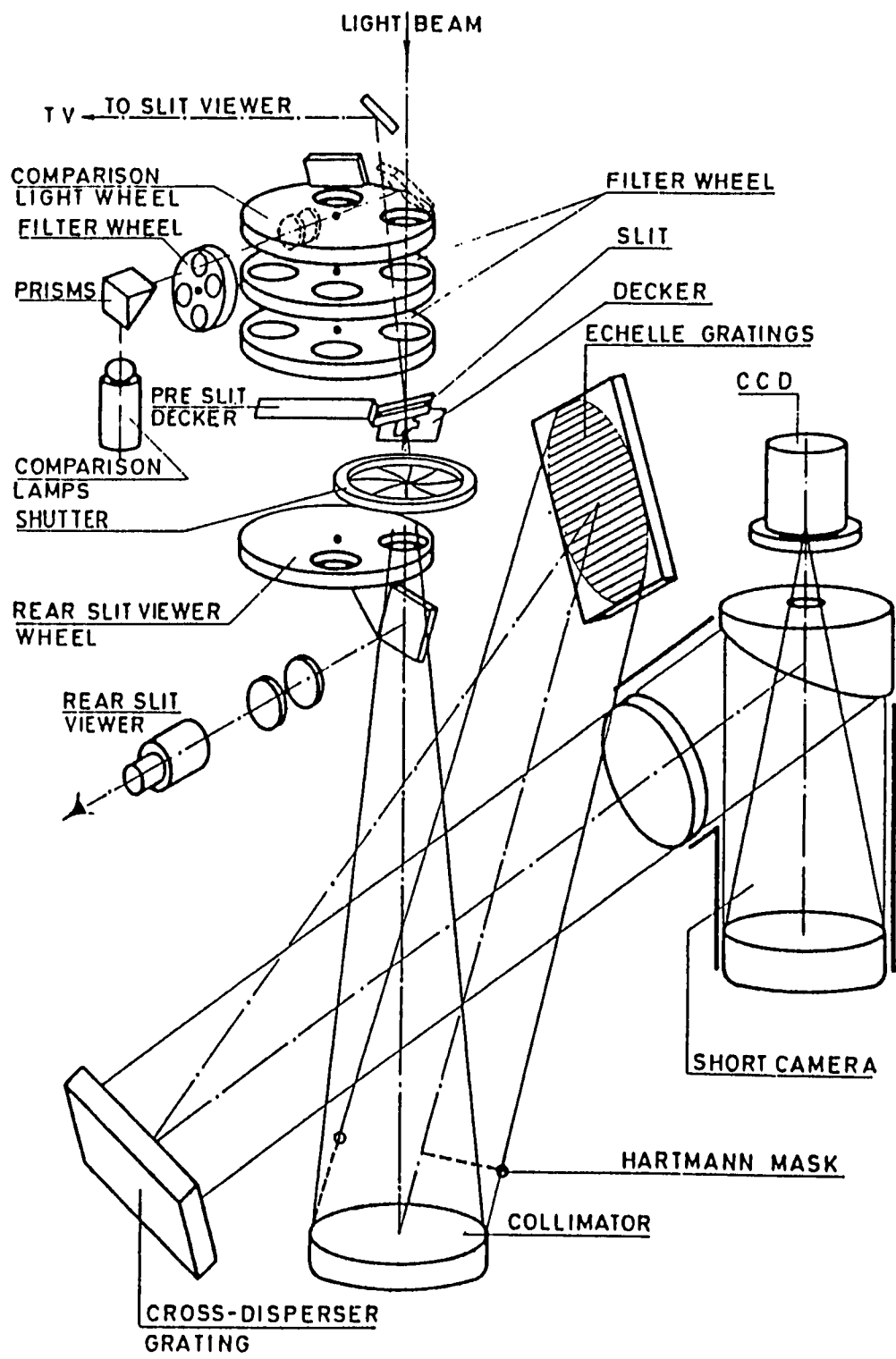


Figure 2.1: Optical layout of CASPEC

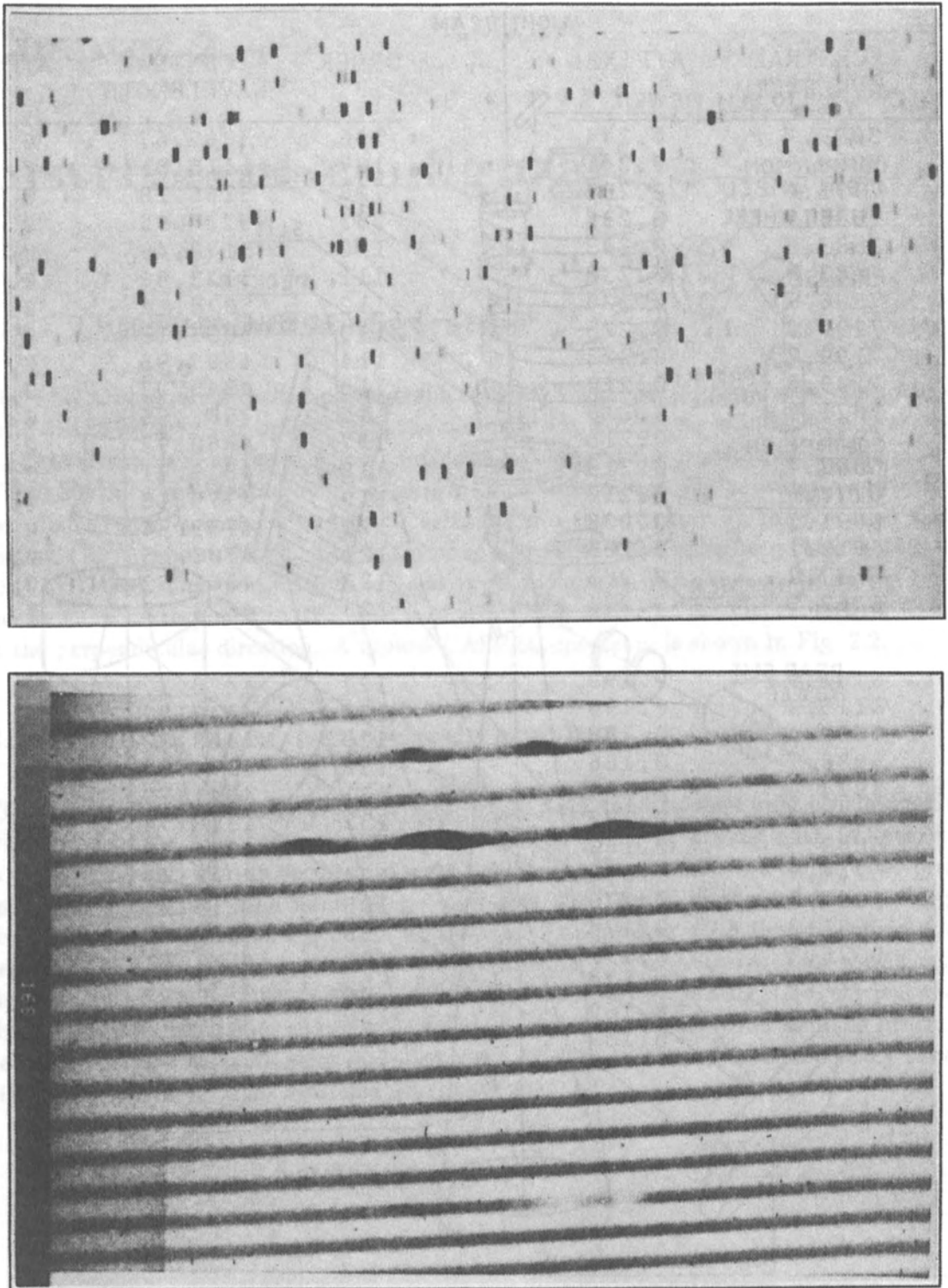


Figure 2.2: Typical CASPEC spectra in the standard configuration

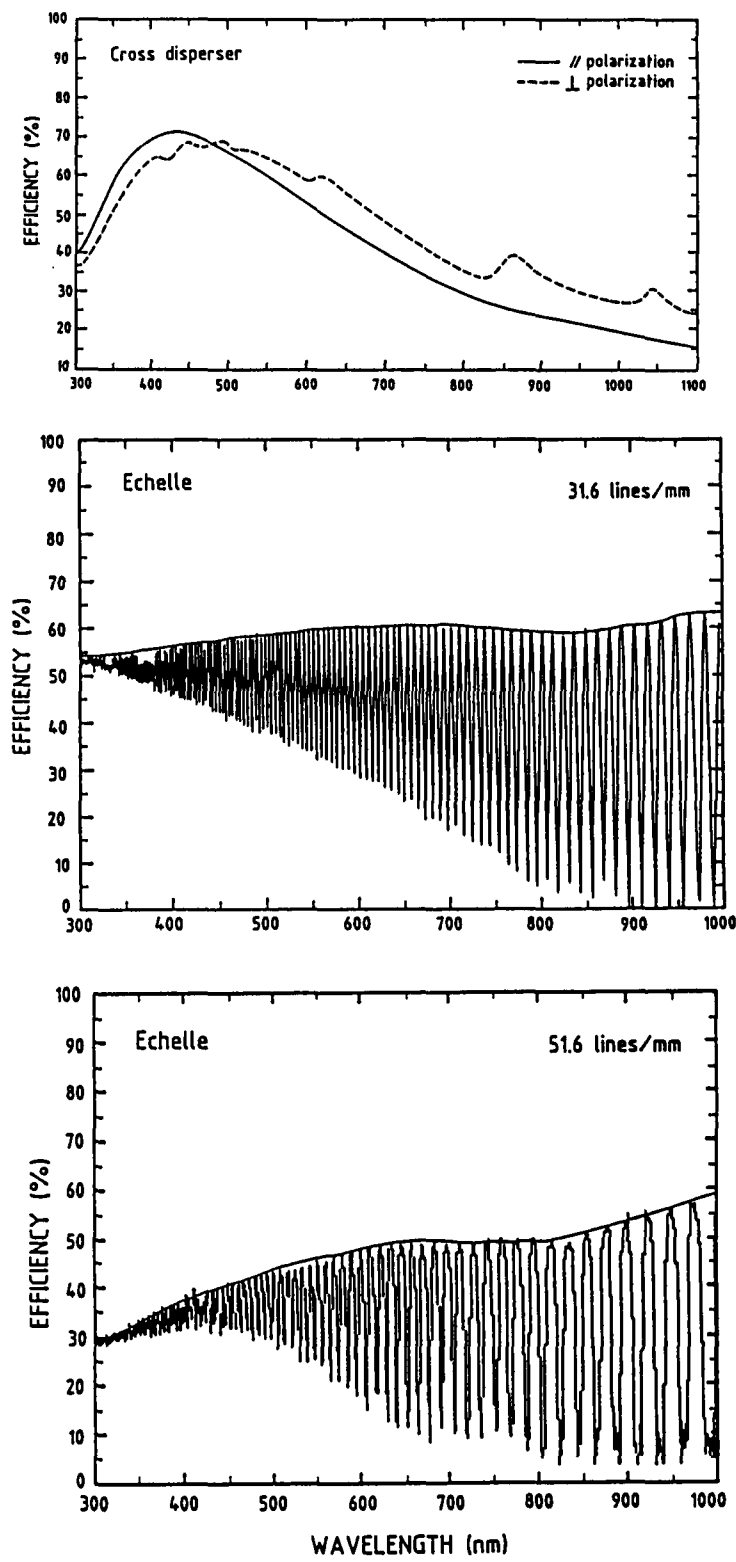


Figure 2.3: Efficiency curves of the CASPEC gratings

2.3 The Zeeman analyzer

The Zeeman analyzer is an optical module mounted in the rear slit viewer unit, that allows circular or linear polarization to be measured. The module consists of a $\lambda/4$ plate and a Wollaston prism that split the incoming light into two parallel spectra of orthogonal polarization. Any polarization of the incoming light will show up as an intensity difference between the two spectra. Since the instrument produces two spectra for each order, the orders are no longer separated for wavelengths shorter than $\lambda \sim 5500 \text{ \AA}$ for the 31.6 lines/mm grating and shorter than $\lambda \sim 4500 \text{ \AA}$ for the 52 lines/mm grating.

Since each of the spectra contains at most half the incident light, and due to the increase in the number of interposed optical elements, the limiting magnitude in polarimetric mode is significantly brighter than in the standard mode.

The Zeeman analyzer has to be set for linear or circular polarimetry during the day (cannot be changed remotely), but the unit can be inserted into the light path from the control room, using the appropriate exposure definition command.

2.4 Long slit mode

By replacing the cross disperser by a flat mirror and by using an interference filter, a spectral region can be isolated. If the filter width is narrower than an echelle order, a long slit can be used without superposition of orders. The maximum slit length is 2 cm, which corresponds to $144''$ on the sky. Fig. 2.4 shows the format of a thorium lamp exposure and the spectrum of a planetary nebula as obtained in this mode. The standard (40 mm) filters now available on the special Long Slit wheel are:

Table 2.1: Standard CASPEC filters

Position	Filter (λ_c /bandpass)	Peak transmission
0 _____	Free	
1 _____	5017/52 \AA	70%
2 _____	5045/52 \AA	69%
3 _____	6572/48 \AA	64%
4 _____	6634/51 \AA	61%
5 _____	Free	

No other 40 mm filters are presently available in the ESO inventory.

The focusing is normally done by the operations group during the afternoon before a new observer begins (see section 5.1). Since the filter center wavelength may not correspond to the echelle blaze wavelength, a small tilt of the echelle may be needed to center the central wavelength on the detector. Filter changes can be performed during the night by calling the Operations Group. Please inform the La Silla Staff as soon as possible if you

require this service.

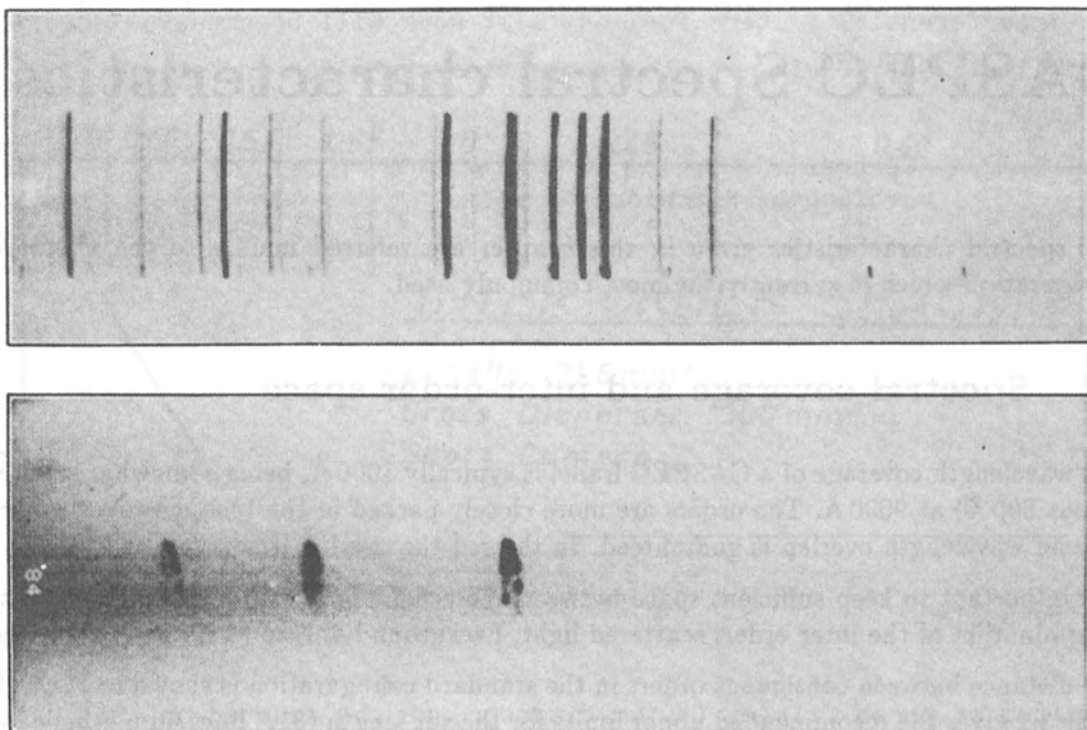


Figure 2.4: A 15 m exposure of the planetary nebula NGC 2818 in the long slit mode is shown together with the corresponding thorium lamp exposure. An $H\alpha$ filter was used in combination with the 31.6 lines/mm echelle grating. Note that the CCD was binned horizontally.

2.5 Long camera

As an alternative to the short camera (section 2.1), a long camera can be mounted on CASPEC. This long camera ($F = 560$ mm, aperture $f/3$) provides a high resolution mode (~ 2 times higher with respect to the standard configuration) giving a resolution of about 50.000 for critical (i.e. 2 pix) sampling with detectors having 15μ pixels. However, this resolving power can be fully achieved only with a very narrow entrance slit corresponding to $0''.6$ on the sky.

Note that the presently used CCD is not large enough to give continuous spectral coverage (order overlap) for wavelengths longer than about 4000 \AA with the 31.6 lines/mm echelle.

Chapter 3

CASPEC Spectral characteristics

The spectral characteristics given in this chapter are referred mainly to the standard configuration which is currently the most commonly used.

3.1 Spectral coverage and inter-order space

The wavelength coverage of a CASPEC frame is typically 1000 Å, being somewhat smaller (about 800 Å) at 9000 Å. The orders are more closely packed in the blue, however, where a broad wavelength overlap is guaranteed. In the red the overlap is smaller.

It is important to keep sufficient space between the echelle orders to permit an accurate determination of the inter order, scattered light, background and to facilitate reductions.

The distance between contiguous orders in the standard configuration is shown in Fig. 3.1. Table 3.1 gives the recommended upper limits for the slit length (31.6 lines/mm echelle) as a function of wavelength. The corresponding values for the 52 lines/mm can be obtained by multiplying these values by 1.6. If the long camera is used, all values should be multiplied by 1.9.

Table 3.1: Recommended maximum slit lengths (standard configuration)

Central λ (Å)	3800	4500	5500	6500	7500
Max. slit length (μ)	280	420	700	1540	1960
($''$)	2	3	5	11	14

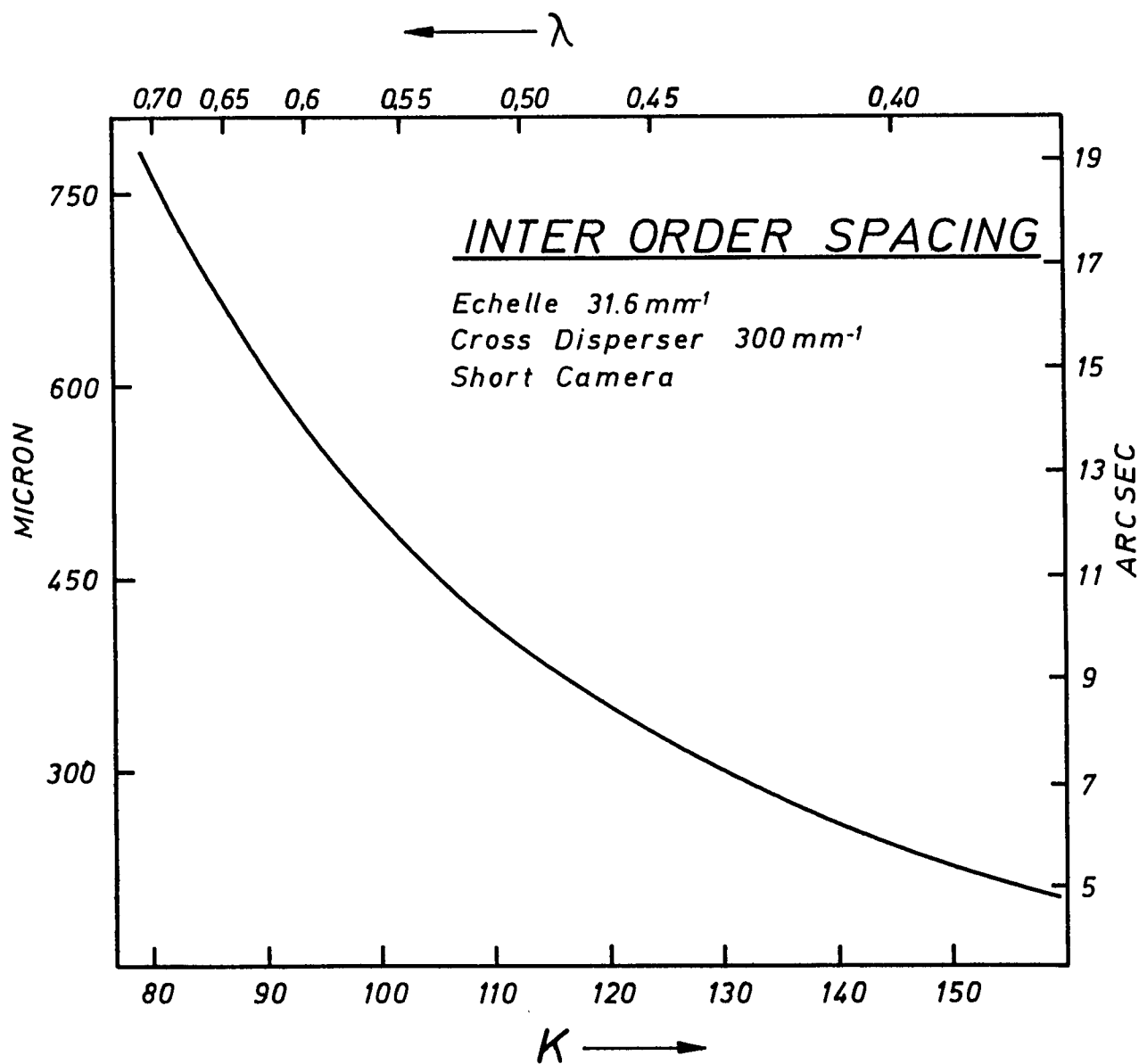


Figure 3.1: Inter-order spacing on the CCD as a function of wavelength

3.2 Spectral resolution

A well known property of echelle spectrographs is the constancy of the product of wavelength with angular dispersion (i.e. of the resolving power [4]). Table 3.2 gives the central wavelength and the reciprocal linear dispersion ($\text{\AA}/\text{mm}$) for several orders with the 31.6 lines/mm echelle. The corresponding values for the 52 lines/mm echelle are almost identical. The computation for other wavelengths is then straightforward.

From the values of Table 3.2 the maximum resolving power can be estimated. Considering the maximum resolving power as given by the Nyquist criterion (two pixels FWHM), and a pixel size of $15\ \mu$, the maximum resolving power achievable with the 31.6 lines/mm grating is about $R = 3.4 \times 10^4$, which is obtained with an entrance slit of $170\ \mu$ or $1''.2$. To decrease the entrance slit below this limit produces undersampled spectra and improves only marginally the resolving power.

Table 3.2: Reciprocal linear dispersion of CASPEC with the 31.6 lines/mm grating

Order	Central Wavelength (\AA)	Reciprocal linear disp. ($\text{\AA}/\text{mm}$)
150	3768	3.9
140	4070	4.2
130	4381	4.5
120	4732	4.8
110	5152	5.3
100	5671	5.8
90	6319	6.5
80	7126	7.2
70	8122	8.3

3.3 CASPEC limiting magnitudes

The measured efficiency of CASPEC is shown in Fig. 3.2, calculated from one observation of the standard star LTT 1020. An estimate of the S/N for stars of different magnitudes has been derived using the measured efficiency of CASPEC + CCD # 8 at $5560\ \text{\AA}$ ($\sim 3.4\%$ or $1\ \text{e}^{-1}/\text{sec}/\text{\AA}$ for a $V = 15^m.9$ star). We considered the light to spread over 4 ($15\ \mu\text{m}$) pixels in the direction perpendicular to the dispersion and a dispersion of $0.078\ \text{\AA}$ per pixel. Photon statistics, read-out noise and dark current of CCD # 8, as given in Appendix A, were used to calculating noise. The final results are shown in Fig. 3.3.

For faint objects the limiting factor is the read-out noise of the CCD. This may be reduced by binning the CCD in the direction perpendicular to the dispersion. Note, however, that this increases the rate of radiation events per pixel and also enhance some CCD defects.

We stress that this figure must be taken as indicative only. In fact, several considerations

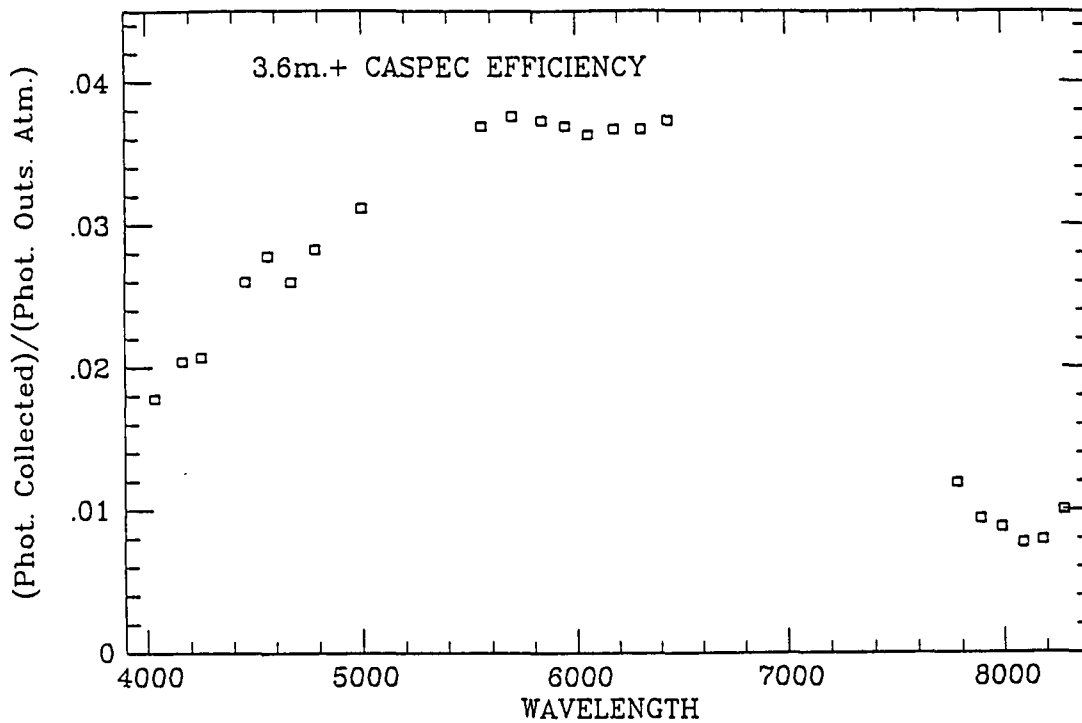


Figure 3.2: Overall 3.6 m telescope + CASPEC efficiency

We stress that this figure must be taken as indicative only. In fact, several considerations apply:

- When used at maximum resolving power, the CASPEC performance is strongly seeing dependent.
- For S/N ratios above about 100 the limiting factor is the accuracy of the flat field correction.
- For S/N ratios between about 10 and 50 the limiting factors are the linearity of the CCD at low light levels, the behaviour of the dark current, and the read-out noise.
- To approach the theoretical S/N the spectrum must be confined to a few pixels in the direction perpendicular to the dispersion.

For bright objects it is useful to widen the spectrum so that the flux is distributed on more pixels at a given wavelength. With care, S/N ratios approaching 300 are possible in single exposures.

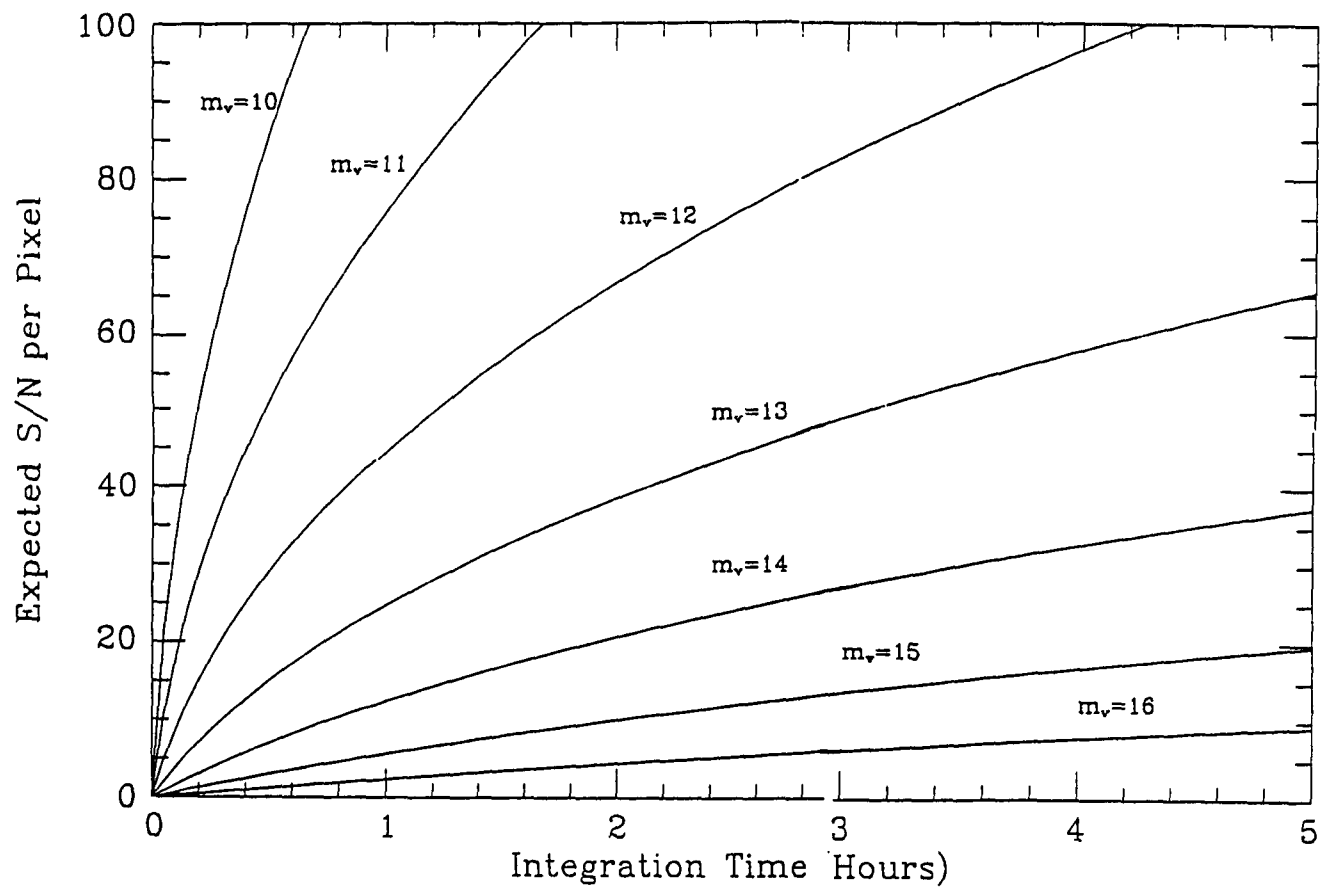


Figure 3.3: The expected S/N ratios per pixel at 5500 \AA as a function of exposure time for stars of different magnitudes. Basic assumptions are given in the text.

Chapter 4

Observations

In order to reduce the data it is necessary to have a wavelength calibration (Th-Ar) exposure and an exposure that can be used to determine the positions of the orders on the detector. While the exposure used to determine the order position can be the science exposure itself if the object has a strong continuum, it is usually advisable to also provide a flat field exposure. If the detector is cosmetically smooth a flat field exposure may not be necessary in the violet spectral region, but it is useful for removing “fringing” which becomes important at wavelengths longward of 5000 Å. In addition, it is important to also obtain a few dark frames if one is working at wavelengths where the order crowding is sufficiently severe that the determination of the background from the region between the orders is unreliable. Notice, however, that dark frames do not include the scattered light, which is known to be present in CASPEC at the few percent level, and in most cases is the main source of background.

The number of calibration exposures, and the time at which they must be done, are determined by the observer’s program, as we will see below (chapter 5). In the following section we will describe a typical exposure. In the rest of the chapter the parameters for wavelength calibration, flat field, and dark current are discussed.

4.1 Setting an exposure

CASPEC has been designed to be fully controlled via remote software; the setting up, the maintenance, and the observing are controlled via a number of self explanatory “menus” based on softkeys. The main “menu” has the following options:

CASP	CCD		
	LOG	IHAP	TERMINATE

The **CCD** menu allows adjusting several CCD parameters. In particular, the key **CCD frame/binning** leads to a form that permits the observer to define the format of the frames and the “size” of the pixels, which can be adjusted by electronically binning

together up to 20×20 CCD pixels during read out.

The control program of CASPEC is entered by logging in the softkey **CASP**.

The CASP menu has the following softkeys:

OBSERVATION	Telescope setting	DISPLAY PARAMETERS	Help
Reinitialise Functions	MAINTENANCE	Status	Terminate

Pressing **OBSERVATION** leads to a menu which allows the setting for the desired observation. **Define Exposures** gives a form which must be filled according to the observers' wishes. Even if the form is self-explanatory, some remarks are necessary:

- Exposure types: RE for a Regular Exposure, FF for Flat Field and DK for DarK. Defining a DK exposure results in the shutter remaining closed during the exposure. However, if a lamp has been turned on (as for a FF exposure), changing the exposure type (i.e. to RE) does not turn the light off. The observer must re-define the Light Source parameter. *Check at the end of the night and after doing tests in the afternoon that no lamp is left on.*
 Light Source: 0 No lamp; usually the lamps used are
 1 Quartz lamp for flat fielding
 5 Th-Ar lamp for wavelength calibration.
- Slit Width: in either microns or arcsec ($100\ \mu\text{m}$ on the slit = $0''.72$ on the sky and $17.6\ \mu\text{m}$ on the detector).
- Slit length: microns or arcseconds scale: $100\ \mu\text{m}$ on the slit = $0''.72$ on the sky and $30\ \mu\text{m}$ on the detector.
- Collimator Focus: must be changed only when the central wavelength is changed. See chapter 5.1.1.
- Neutral and colour filters: the parameters of the filters are given in Table 4.1. Filters are used for flat field and Wavelength Calibration exposures (see below), or to block UV-blue light when working at red or IR wavelengths.
- Rear slit viewer: Must be set to "2" when working with Zeeman Analyzer.

When the exposure form is correctly filled, you are ready for your exposure: pressing ENTER enters the parameters you have chosen and returns the OBSERVATION menu, then pressing **START EXPOSURE** sets up the chosen parameters and the observation begins. *Note that the chosen parameters are set by the software at the moment the exposure begins and not at the moment of the definition!*

Sometimes a Function Fail can happen for one or more of the remote CASPEC functions and the functions must be reinitialized: go to the **Previous Menu**, i.e. the CASP menu, and press **Reinitialize functions**. A list of functions will be displayed. Press ENTER.

Then a second list will be displayed and you will be asked if you want to reinitialize all functions. Type **YES** if the **cross-disperser is not disabled and locked** (See section 5.3). Otherwise type **NO**, and enter $-5, -8, -11, -13$ and “RETURN” to identify functions that are **not** to be reinitialized.

4.2 Flat field exposures

Flat Field exposures can be obtained by using the quartz lamp in the spectrograph (lamp 1). With the present MIDAS reduction procedure the FF can also be used to fit the CASPEC orders. The flat field can also be used to correct the stellar spectrum for the echelle blaze function and the pixel to pixel variations. Notice that the blaze function determined using the internal FF lamp may be slightly different from that of the objects. As we already mentioned, the FF correction can be the major cause of uncertainty for high S/N observations. When using CCD detectors in the red range ($\lambda > 5500 \text{ \AA}$) the presence of strong fringes is easily noticeable, and a good FF is essential to properly correct for this effect. Since the fringe intensity is slightly dependent on the exposure level, we suggest to take FF exposures having a number of counts comparable with those of the science exposure; the S/N ratio of the flat field exposure can then be increased averaging many FFs.

It is also important to take FF using a longer slit than used for the science exposure; this is to guarantee a complete overlap between the FF and science exposure pixels. In fact, as we will see below [see section 5.3], some small shifts can be registered between two different observations. Short slit FFs are useful for obtaining an accurate determination of the echelle order positions during the data reduction.

Exposures of few seconds (2–5) are long enough to get well exposed FF spectra. We suggest to use the ND filter # 3 in the blue, the ND filter # 2 in the green, and the ND filter # 1 in the red. For wavelengths shorter than 5000 \AA the use of colour filter number 3 is recommended to decrease the count level at the red end of the spectrum.

Table 4.1: CASPEC neutral density and colour filters

Position	Neutral Density	Colour
0	Free	Free
1	1.9	LWP 6250 \AA
2	1.36	LWP 5350 \AA
3	0.90	BG 38
4	0.53	
5	0.33	

LWP: Long wave pass

4.3 Wavelength calibration exposures

Generally, the lines from a Th-Ar lamp (lamp number 5) are used for wavelength calibration. In the blue this lamp is used without filters, while a colour filter (number 1) must be used for red wavelengths ($\lambda > 7000 \text{ \AA}$) to avoid second order contamination. The following table (Table 4.2) shows approximate Th-Ar exposure times:

Table 4.2: Th-Ar indicative exposure times

λ_e	Exp. Time (sec)
4300	10
5000	10
6000	10
7000★	30
8000★	60

★Color filter 1 should be inserted to avoid second order contamination

To get very precise wavelength calibration longer exposures are suggested (i.e. 60 sec); with these exposures the strongest lines will be saturated, but many faint lines will be detectable by the reduction routines. We suggest also to use the Th-Ar CASPEC Atlas [ref. 4] to check, for each setting, the centering of the instrument at the chosen wavelength.

4.4 Dark exposures

CCDs have a bias level (normally about 200 ADU) that can be evaluated averaging several short DK exposures (1 sec). By using these exposures the observer can also check the CCD read out noise using the IHAP SAMPLE command. Note, however, that Bias exposures are not used in the ‘standard’ MIDAS CASPEC reduction, where the background correction is made by a two dimensional fit to the inter-order background. This allows other effects, such as scattered light, to be taken into account.

Long Dark exposures (lasting at least as long as the longest science exposure) are useful to monitor the CCD dark current. The Dark exposures can be done during the day. If the voltages and the temperature of the CCD are kept constant (which is normally the case), only one set of Dark calibrations per run will be sufficient.

Note

Note that the spectrograph is not completely light tight, so long dark exposures should be taken with the lights in the dome switched off! Put a sign “Dark exposure running. Do not enter” on the door of the control room and lock from inside the other doors to the dome.

Chapter 5

Observing run: examples and advice

The observing strategy (i.e. the sequence of exposures and settings) strongly depends on the observer's program and targets. As extreme examples, we consider below a case in which high S/N data and many instrument settings are required during the night (sect. 5.4), and the case of observations of faint objects where the same setting is used for a full night, (sect. 5.3).

5.1 Preparation of the instrument

Independently of the observing program, several steps in the preparation of the instrument are common to each observer. This preparation can be done in the afternoon and at the very beginning of the night .

5.1.1 In the afternoon

- Check with the Operation Group the collimator focus for the desired spectral range(s). Note that in order to have focus values covering the whole spectral range accessible with CASPEC, it is sufficient to determine the focus for 3 central wavelengths. (e.g. at 4200, 6200, and 8200 Å). The collimator values for other central wavelengths can be inferred from these by simple interpolation.
- Check with the Operations Group that the echelle blaze function is well centered in the order. This will greatly facilitate the reductions. Make sure that this is done using dome flats in order to insure that the spectrograph is illuminated in the same way as your science exposures.
- Check with the Operations Group the setting of the instrument and of the CCD. For the CCD you can choose gain, horizontal clock, and binning. The gain and the read-out speed should be set with the Operations Group while the CCD binning can be fixed by the observer from the CCD menu. A slow reading is recommended

for faint objects as it minimizes, e.g. the effect of saturated columns in the image. The choice of the CCD amplifier gain is also important. For faint objects choose a high amplifier gain. You will be less troubled by the digitization of the CCD output and you should get slightly better read-out noise. For bright objects a low gain will allow you to collect more photoelectrons before the dynamic range of the electronics is exceeded.

At this point you are ready to prepare your exposures. By pressing **OBSERVATION** and **Define Exposure** you get the observation form. Bias and calibration exposures can be done at this time. In filling out the observation form remember to:

- Specify the type of exposure (FF,DK,RE).
- Choose (or switch off) the calibration lamps.
- Fix the slit width and height according to required spectral resolution, leaving enough inter-order space.
- Fix the central wavelength and the appropriate collimator focus.
- Choose (or remove) the ND and colour filters.

Warning

If you saturate a CCD image, the next long exposure will show a faint remnant image. The effect can persist for the full night. Thus, avoid saturation whenever possible.

5.1.2 Pointing and focusing

During the night two important procedures are necessary: centering the object on the slit and telescope focusing.

The 3.6 meter telescope is equipped with a center field that allows to see the CASPEC slit in the desired field. Due to some imperfection of the slit jaws, the centering of the object on the slit in the TV monitor does not ensure that the object is *really* in the middle of the slit. In order to properly center the star on the slit, a TV camera has been installed on the rear slit viewing eyepiece. In order to see the star on this camera, a dummy exposure must be performed so that the spectrograph shutter remains opened. This is done as follows:

- Point the star.
- Start a RE (dummy) exposure to open the spectrograph shutter, not transferring it to tape.
- During the exposure type INST,RV,IN to insert the rear viewing mirror.

- Turn on the TV monitor on the right and the image of the object will appear in the slit. Using the handset, move the telescope to find the edges of the slit and then center the star. You will see that on the center field the star will appear slightly offset from the center of the slit.
- Remove the rear view camera by typing `INST,RV,OUT` and turn off the TV monitor.

We have also found that it is best to check the telescope focus using the rear slit viewing camera. After the insertion of the rear viewing mirror, move the telescope focus looking for the value for which the image of the star appears to be most compact. It may be convenient to widen the slit for this operation using the command `INST,SL,1200`. It is recommended to close the slit to the observing value *before* removing the rear slit viewer in order to check that the object remains centered.

5.2 Spectrograph flexure

The CASPEC cross-disperser position is normally set by a servo that continuously “hunts” around the correct position. This widens the spectrum somewhat. For bright objects this is not important, but for faint objects, during conditions of good seeing, the spectrum is wider than optimum.

Apart from the cross disperser problem, small shifts are registered when observing different regions of the sky. This has two major effects on the observations:

1. For very long exposures (i.e. when the CCD read out is the main source of noise) it decreases the S/N because it results in the spectra being spread over more pixels.
2. Since the flexure depends on telescope position, it implies that for very high S/N exposures and for very accurate wavelength calibrations (e.g. as required for radial velocity measurements) wavelength calibration exposures must be repeated before and after *each* stellar exposure.

5.3 Faint object exposures

For long exposures CASPEC has been tested up to 5 hours on a 16–17 magnitude QSOs. This experience shows that, in order to have reasonable S/N observing faint objects, particular care must be taken both during the observations and the data reduction.

- After the instrument set up in the afternoon, it is recommended to clamp the cross disperser; this is done directly (mechanically) on the spectrograph **after the disabling of the cross disperser function**. To disable the cross disperser, press `Reinitialize func's` then ENTER after the 1st table is displayed; answer NO to the question if you want to initialize all the functions, then typing `-5, -8, -11, -13` the cross disperser is disabled — (the minus sign avoids that the corresponding functions

are initialized). Then go into the Cassegrain cage, disconnect the cross-disperser power connector (# 12), and clamp the cross-disperser.

- AFTER clamping make flat field and wavelength calibration exposures; with this configuration they are necessary only at the beginning and at the end of the night.
- Carefully center the star on the slit and focus the telescope.
- Begin the science exposure.
- During the exposure check, from time to time, the centering of the object in the slit using the rear slit viewer. *Note that this check must be done while the observation is running.*
- To minimize the spectrograph flexure rotate CASPEC 180° (typically from 90° to 270°) when crossing the meridian (caution with cables!!). This will partially compensate the flexures.
- At the end of the night again do FF and WC exposures.
- It is wise to perform some long DK exposures (during day time).

In long exposure a large number of radiation events is recorded on the CCD. Special programs exist both in MIDAS and IHAP for their removal. They work efficiently especially when the 15 μ m pixel format of the CCD is used.

5.4 Observations with several wavelength settings

The observational sequence is quite different (and less efficient) if you want to observe in different spectral ranges during the same night with a high S/N and/or an accurate wavelength calibration. Proceed as follows:

- Perform FF and WC exposures in the afternoon for each setting.
- Check the centering of the star on the slit and the telescope focus.
- Set the first spectral range.
- Go to the object.
- Perform FF and WC exposures.
- Science exposure. *Note that if a neutral density filter was used in the previous exposure, the object will be not visible in the guide camera before the next observation is started. It can be removed starting a 1 s dummy exposure without filter.*
- FF and WC exposures again.
- Change central wavelength and repeat the sequence.

5.5 Observations of flux standard stars

The observations of flux standard stars at the same spectrograph setting as the program objects can be used to obtain absolute flux calibration of the spectra or, in a more restricted application, to perform the flat fielding. In order to do it properly the absolute flux measurements must have an appropriate wavelength spacing. At present, data are available (and they are implemented in MIDAS) only for five stars at a 12 \AA resolution. These stars are listed in Table 5.1. Typical exposure times are ~ 30 min. We recommend to open the slit to more than the size of the visible seeing-disk for the standard star observations. Remember to use a narrow slit for the corresponding Th-Ar spectrum.

Table 5.1: Recommended standard stars

Star name	Approximate position	Spectral type	V Mag	Ref
LTT 1020	01 52 – 27	G	11.5	1
LTT 3864	10 30 – 35	F	12.1	1
Feige 56	12 04 + 11	B5p	11.2	2
Kopff 27	17 41 + 05	A3v	10.3	2
Feige 110	23 17 – 05	sd0	11.9	2

1. Stone and Baldwin 1983, M.N.R.A.S. 204, 348.

2. Stone 1977, *Ap. J.* 218, 767.

Other standard stars for which flux calibration exist at comparable or better resolutions can also be used. In those cases, however, the user will have to enter in the MIDAS system the flux table before performing the standard reduction.

Chapter 6

Echelle Data Reduction at ESO

A quick evaluation of the data can be obtained at the telescope, using the IHAP package, running on the HP computer in the control room. Several commands are available to display CASPEC frames and to extract echelle orders.

The IHAP command ECHELLE extracts the spectrum by moving an adjustable slit of variable length along the order. The latter is identified with two cursor position. This command can be used only after an R90 rotation of the original frame.

A complete data reduction program, which includes flat fielding, the background reduction, wavelength calibration, order extraction, merging of orders, and flux calibration is part of MIDAS. (MIDAS Echelle Context). A full explanation of all commands is beyond the scope of this manual and can be found in the MIDAS User Manual.

Bibliography

- [1] D'Odorico, S., Lizon, J.L., Tanné, J.F. 1985, '*The ESO Cassegrain Echelle Spectrograph*', ESO internal technical report.
- [2] D'Odorico, S., Enard, D., Lizon, J.L., Ljung, B., Nees, W., Ponz, D., Raffi, G., Tanné, J.L., '*The ESO Echelle Spectrograph for the Cassegrain Focus of the 3.6 m Telescope*', 1983, *The Messenger* 33,2.
- [3] D'Odorico, S., Ghigo, M., Ponz, D., 1987, '*An atlas of the Thorium-Argon Spectrum for CASPEC in the 3400-9000 Å Region*', ESO Scientific Report N. 6.
- [4] Schroeder, D.J., 1970, *Publ. Astron. Soc. Pacific* **83**, 1253.

Appendix A

CCD for CASPEC

For the time being, the only tested detectors suitable for CASPEC are CCDs. The CCD currently (March 1989) mounted is ESO CCD # 8. The CCD efficiency curve is shown in Fig. A.1 and its characteristics are given in Table A.1. The low read-out noise and the low dark current make this detector one of the most appropriate for CASPEC, particularly for observations of faint objects.

These characteristics can be reached only after the detector has been switched on for many hours (typically about 1 day). Therefore, in programming the observing run it is better to observe the brighter objects before the fainter. It is recommended to determine the actual read-out noise using bias exposures. Ask the Operations Group for the value of the gain for your particular set-up.

Table A.1: CCD # 8 Characteristics

Type	: RCA SID 503 High Resolution, thinned, backside illuminated.
Serial number	: 5103-2-6
Format	: 1024 × 640 pixels
Pixel size	: 15 × 15 microns
Image size	: 15.6 × 9.8 mm
Conversion factor	: Normally used at G20 i.e. 1.5 e ⁻ /ADU
Noise level	: At slow read-out, noise decreases to 24 e ⁻ , but read-out takes app. 1 min.
Linearity	: Better than 0.1% even at very light levels. CCD saturation is about 150.000 e ⁻ /pix.
Blemishes	: There is a dead vertical column X41 with constant signal, independent of integration time. Area with much less sensitivity between X243, X244 & Y327, Y389. Several column pairs with small negative/positive offset. The output amplifier produces some light, affecting a small area at the lower left corner.
Dark current	: The mean dark is app. 7 e ⁻ /pix/hr at 140K.
Charge transfer	: Very good in both directions. No preflash is required.
Operating temp.	: 140 Kelvin

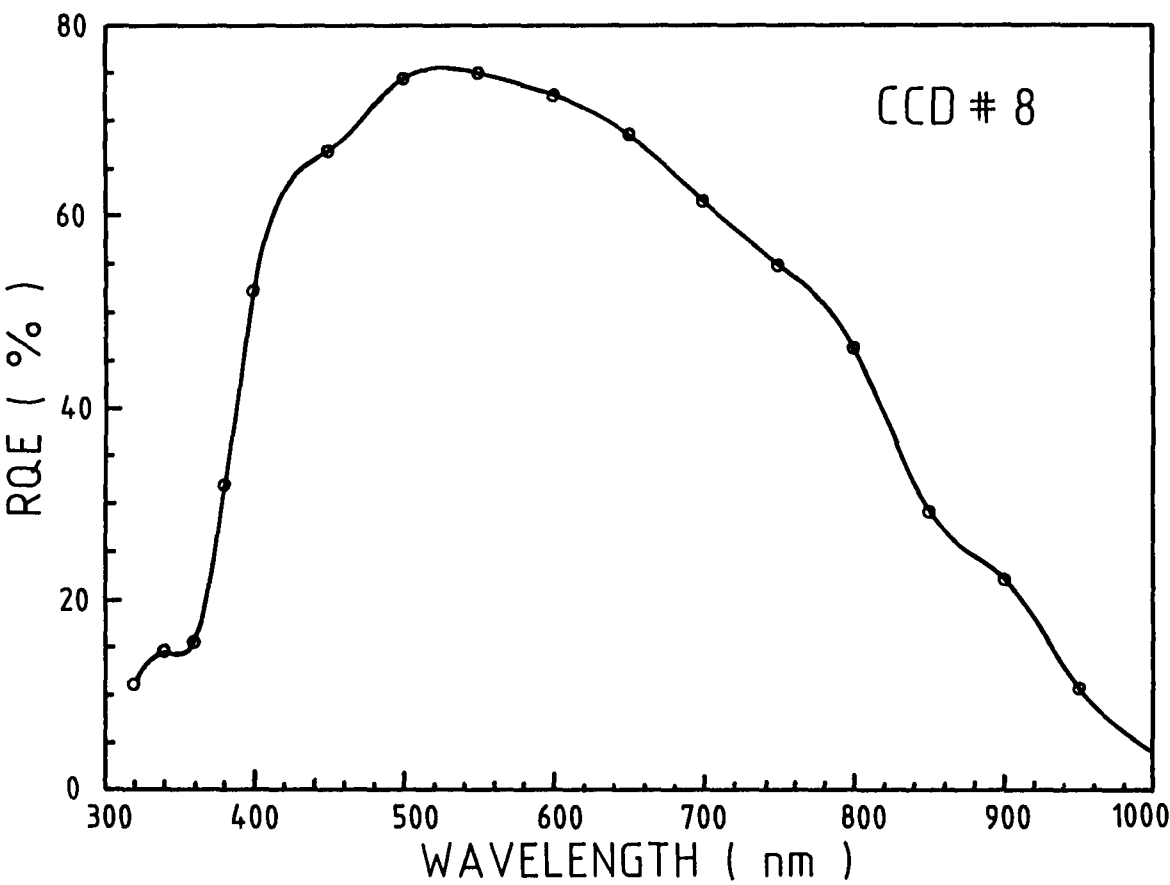
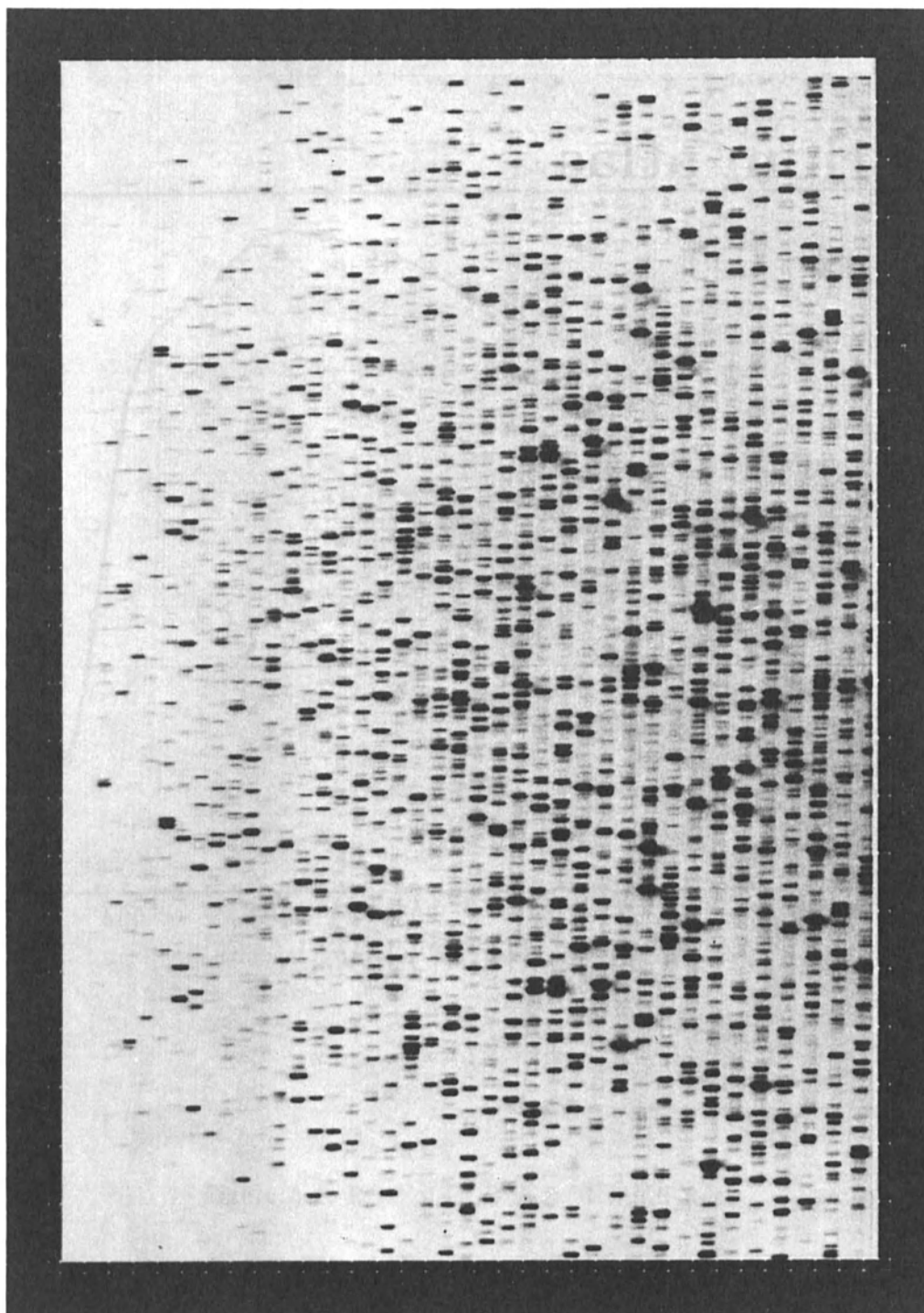


Figure A.1: RQE of CCD # 8 (RCA Hi-Res)

Appendix B

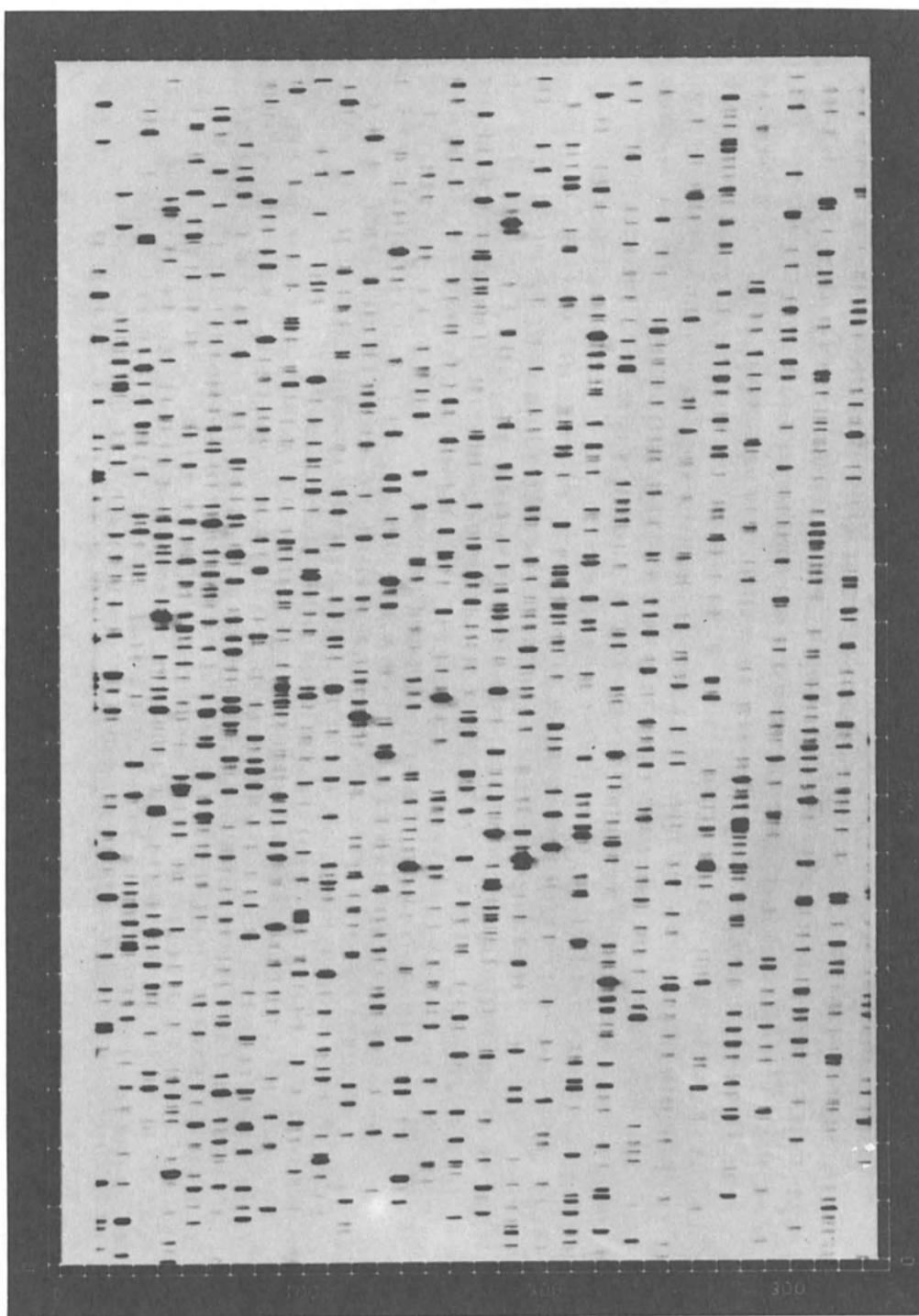
Thorium atlas

$\lambda_c = 400 \text{ NM}$



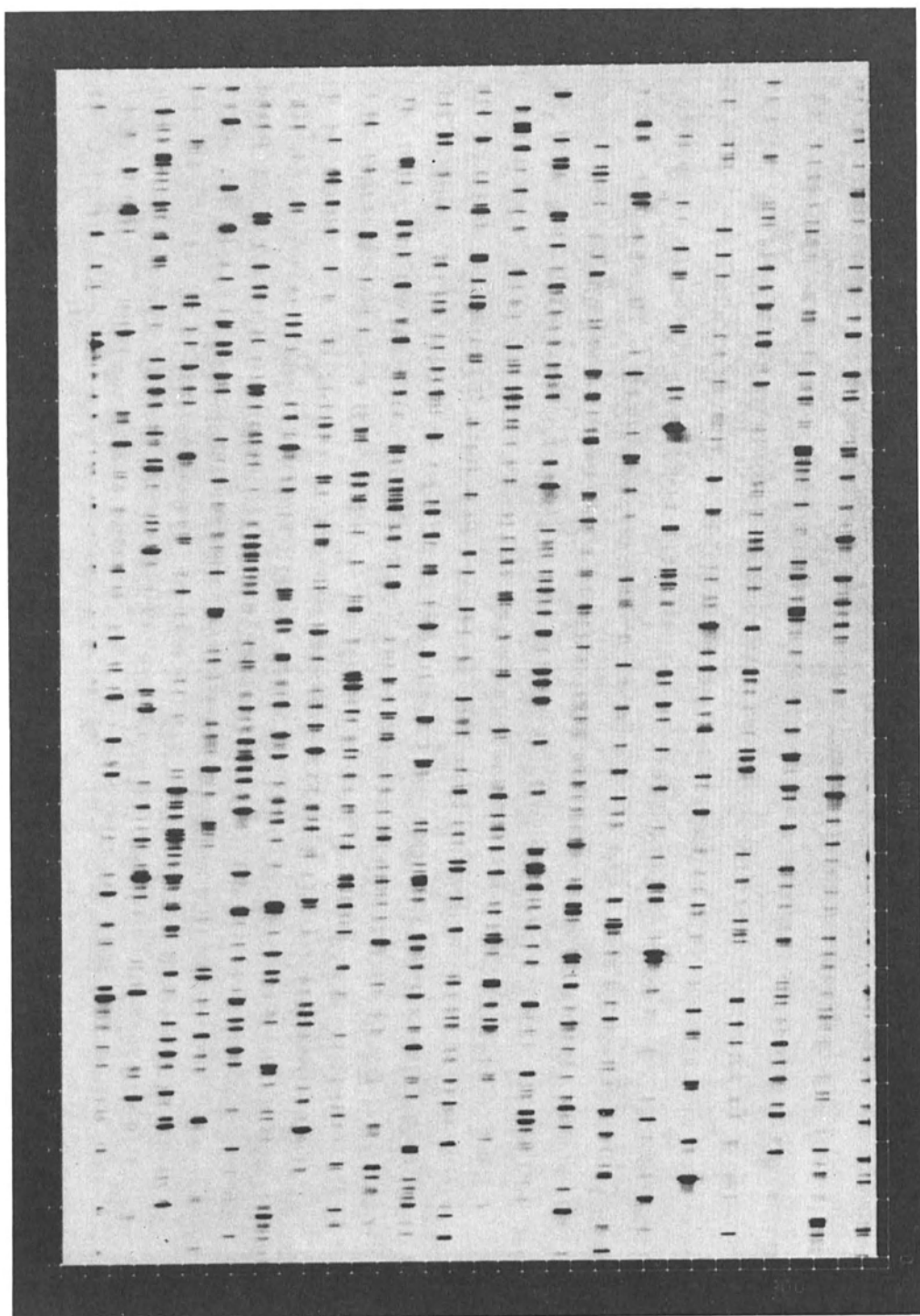
↑ 152
↑ 148
↑ 144
↑ 140
↑ 136
↑ 132
↑ 128

$\lambda_c = 475 \text{ NM}$



134 130 126 122 118 114 110

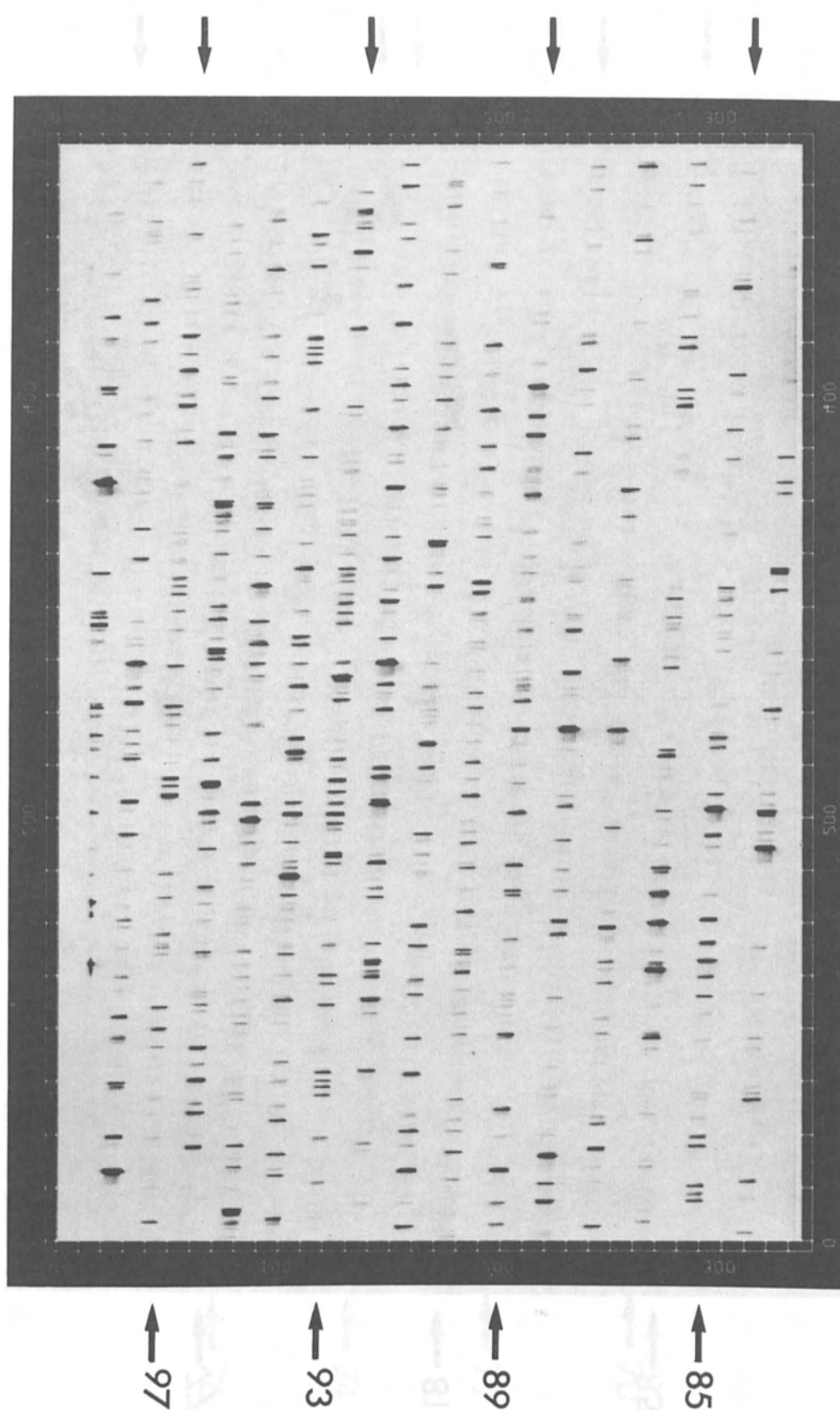
$\lambda_c = 550 \text{ NM}$



↑ 112
↑ 108
↑ 104
↑ 100
↑ 96

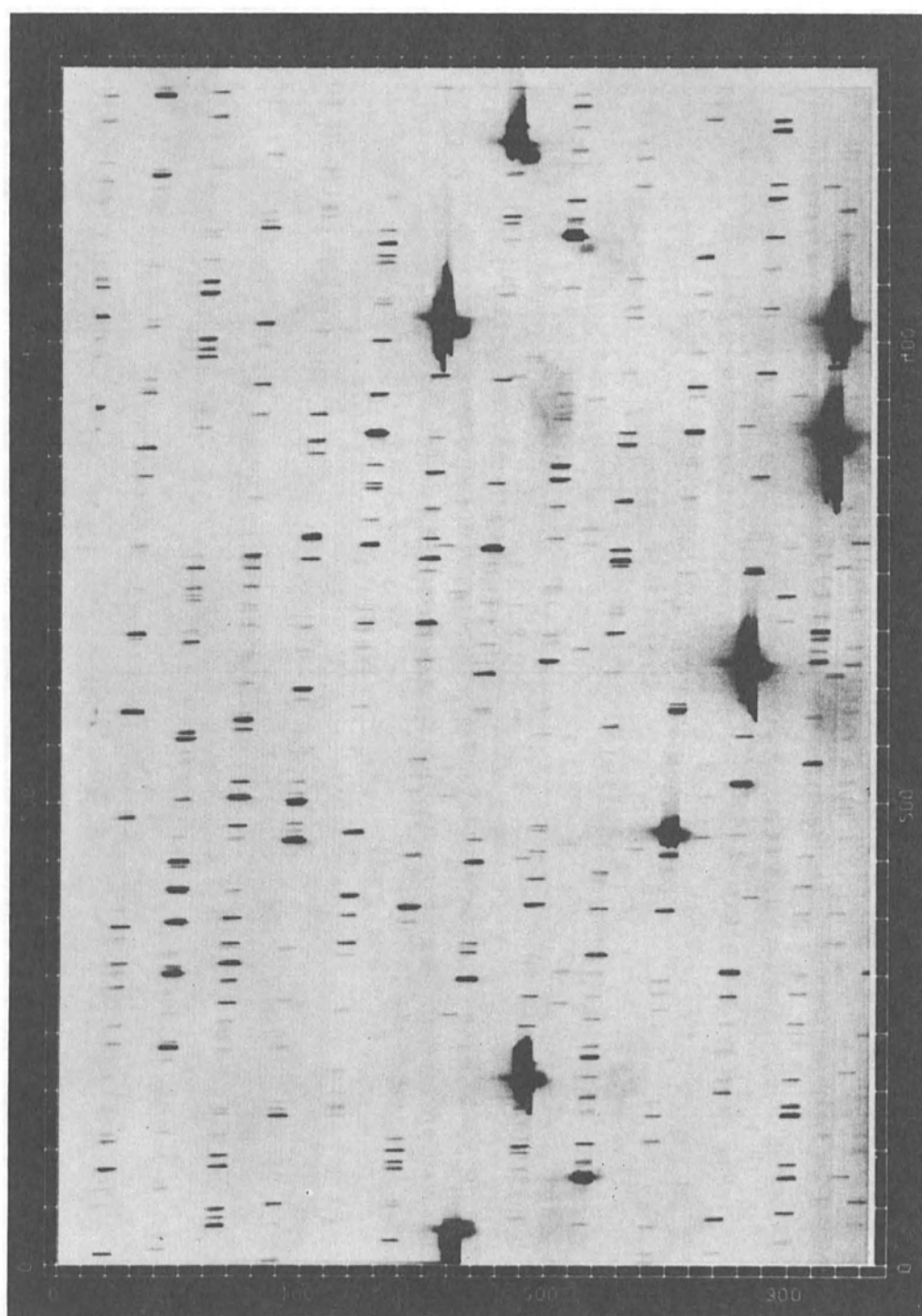
$\lambda_c = 625 \text{ NM}$

$\lambda_c = 625 \text{ NM}$



$\lambda_c = 700 \text{ NM}$

$\lambda_c = 700 \text{ NM}$



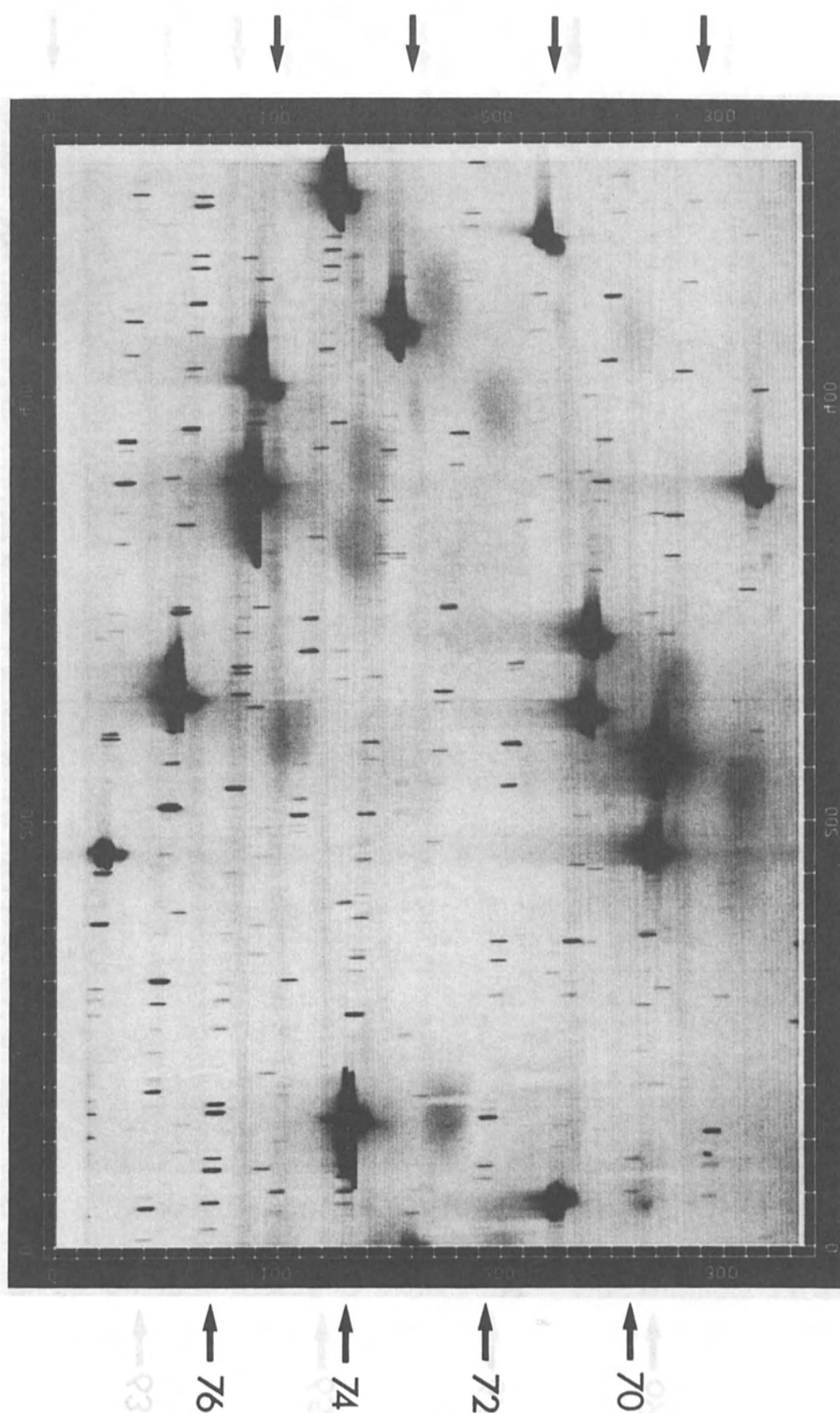
85

81

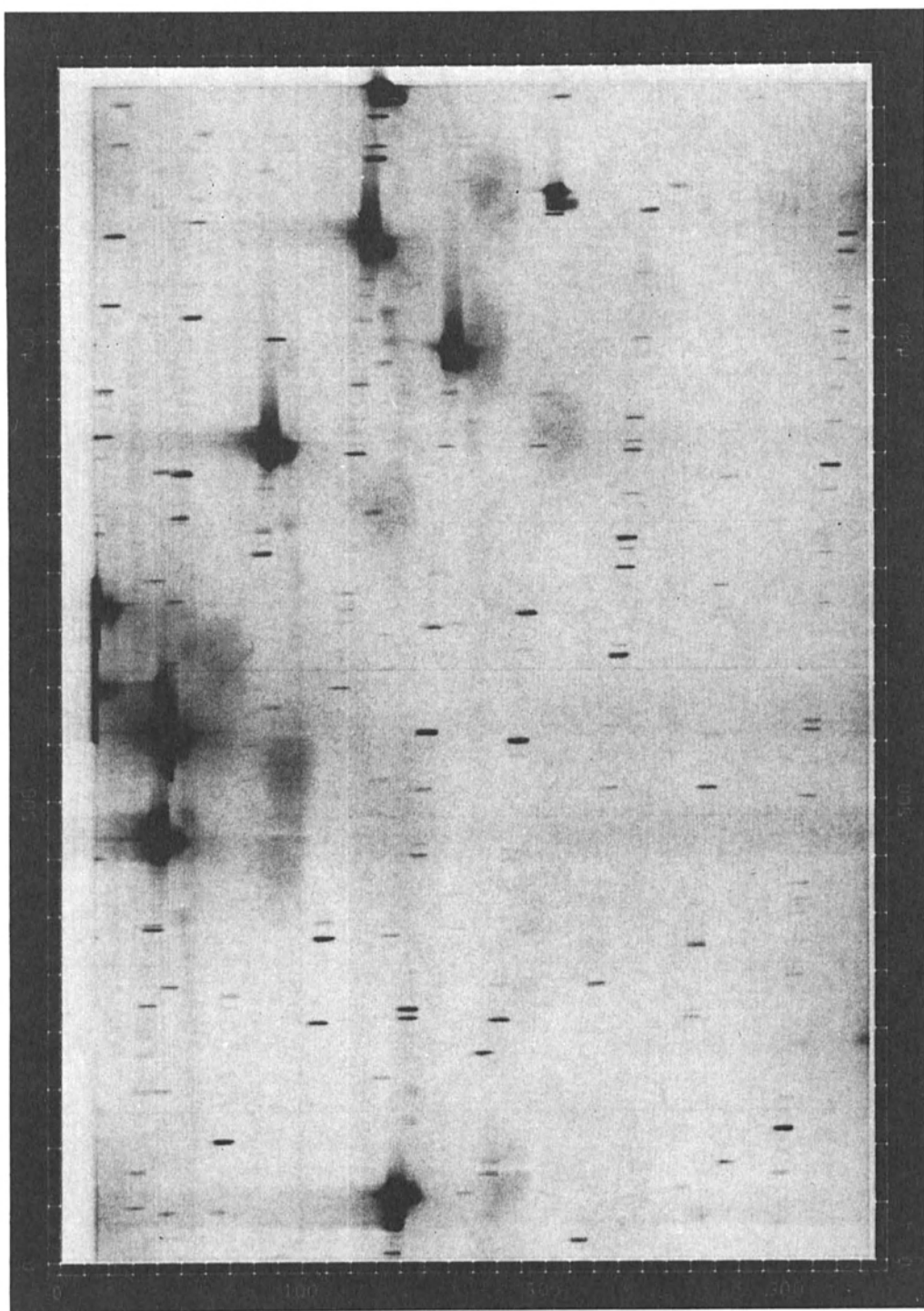
77

$\lambda_c = 775 \text{ NM}$

$\lambda_c = 820 \text{ NM}$

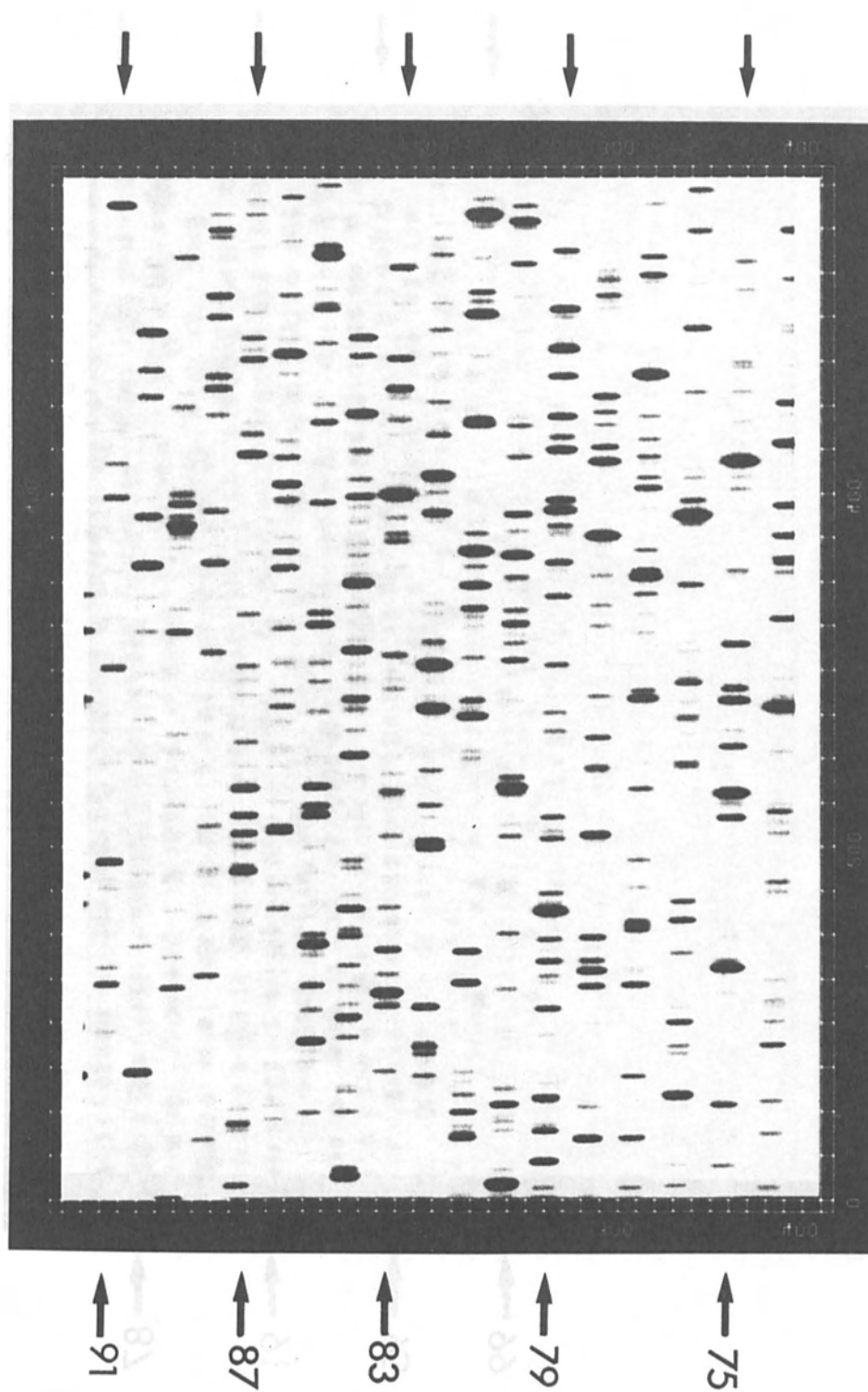


$\lambda_c = 850 \text{ NM}$



69
67
65
63

$\lambda_c = 420 \text{ NM}$



$\lambda_c = 350 \text{ NM}$

