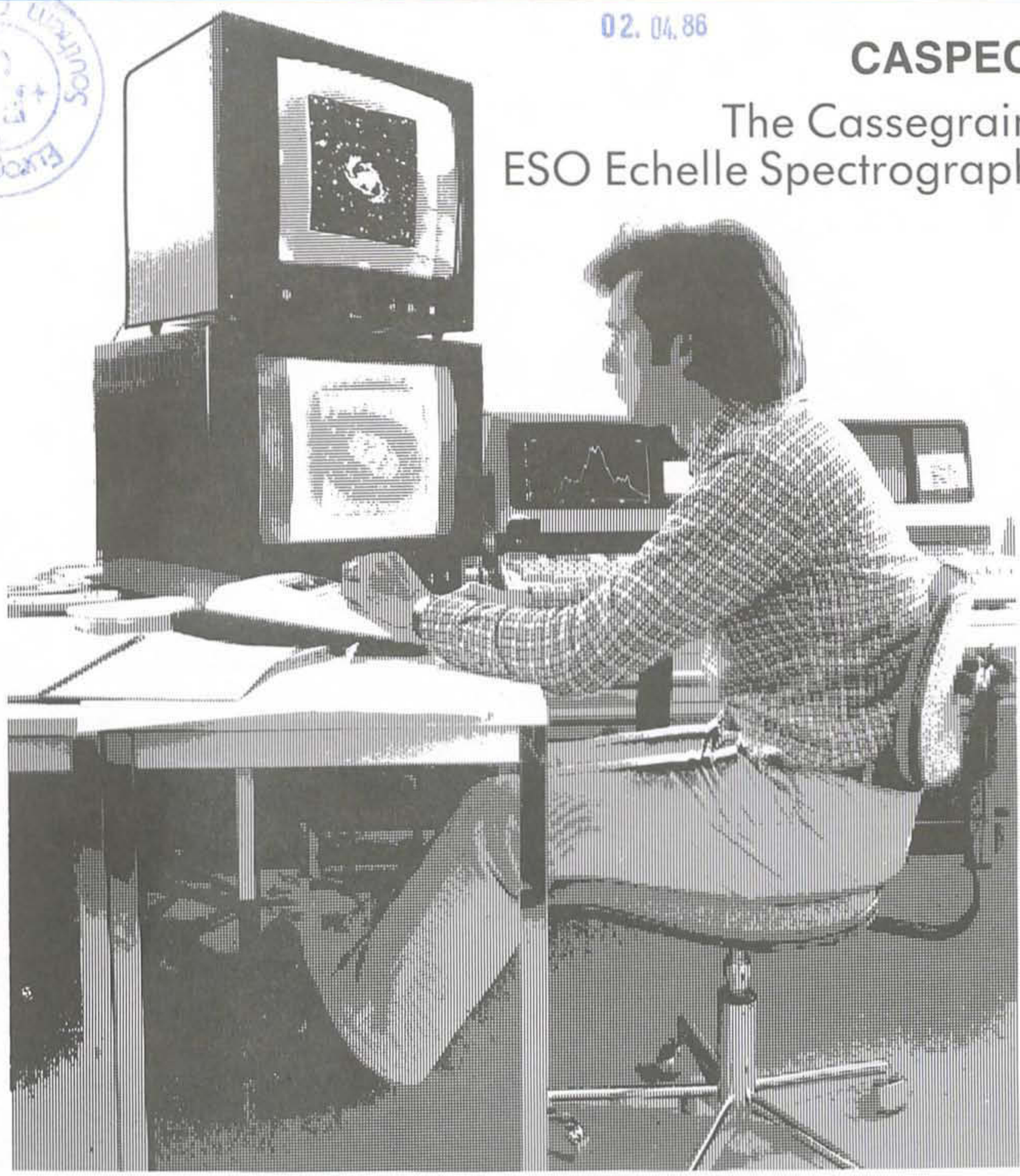
EUROPEAN SOUTHERN OBSERVATORY

OPERATING MANUAL

No. 2 – August 1984

CASPEC

The Cassegrain ESO Echelle Spectrograph



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CASPEC,

THE CASSEGRAIN ESO ECHELLE SPECTROGRAPH

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ESO OPERATING MANUAL

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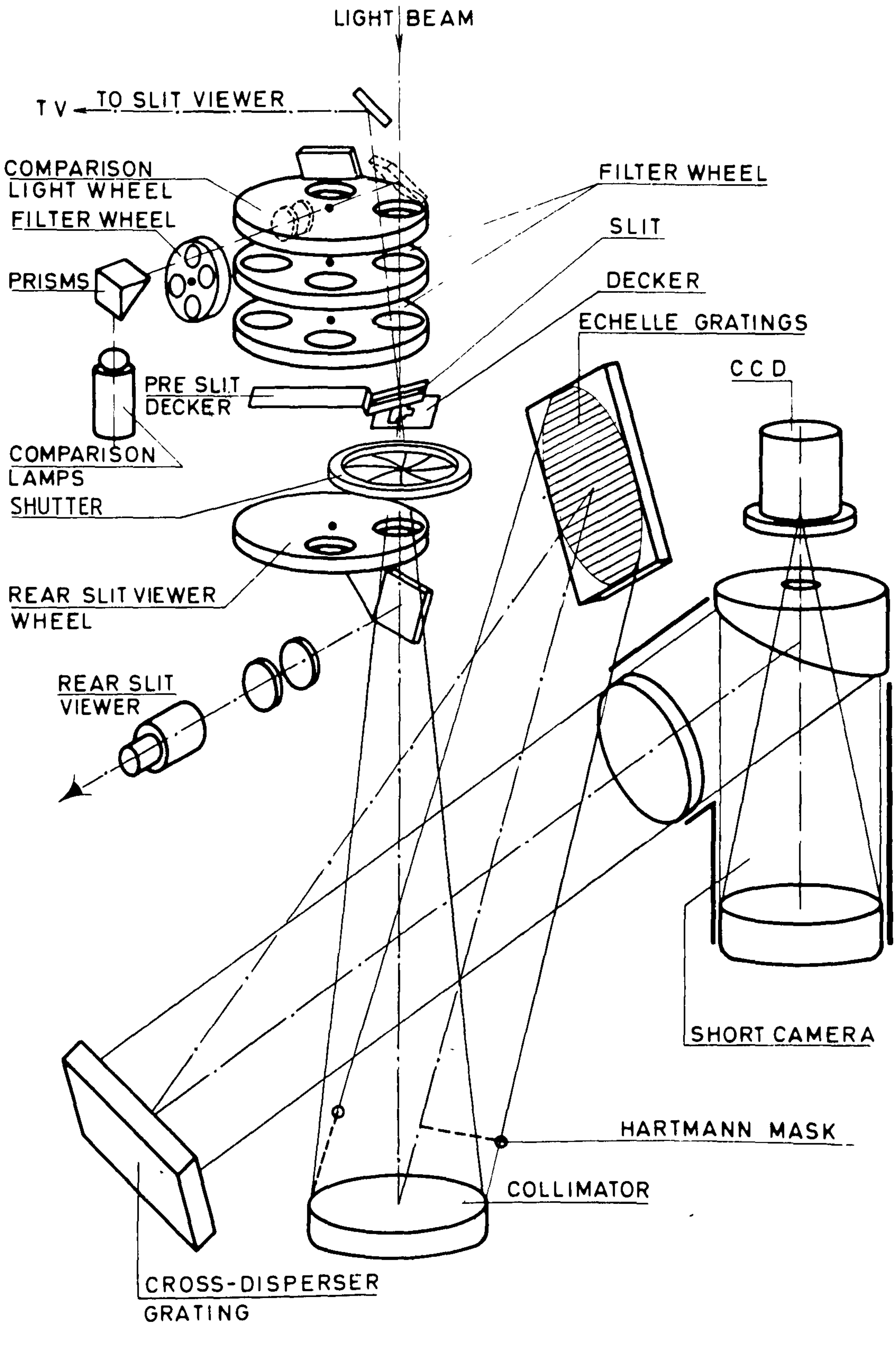

Fig. 1: Optical layout of CASPEC.

I Introduction

This manual describes the present configuration of the instrument and its capabilities on the basis of the experience gathered during the commissioning period. Its purpose is to serve as a general guide to CASPEC users. The final choice of the instrumental parameters depends eventually on the specific scientific program to be carried out and hence rests on the observers.

II The Standard Configuration

a) Optical layout and detector

The optical layout of CASPEC is outlined in Fig. 1. In the standard configuration which is presently offered to the users, an échelle 31.6 lines/mm^{-1}, a cross disperser 300 lines/mm^{-1} and the so-called short camera (291 mm, f/1.46) are used. Details on the optical layout and components can be found in ref. 1. A thin back illuminated RCA chip is currently in use as a detector. It is a 512 row by 320 column device with pixels of 30 x 30 µm. This size corresponds to 1.22 and 0,7 arc sec at the slit in the direction of the disperser and perpendicular to it. The CCD chip used in the commissioning period had a read-out noise of 40e$^-$/pixel and a dark current of 15e$^-$/hour pixel at T = 150°K; the conversion factor was 15e$^-$/ADU. The quantum efficiency curve of this CCD is shown in Fig. 2. The saturation level is at 16000 ADU.

The columns of the CCD are normally oriented in the direction of the long dimension of the slit. An example of a spectrum is shown in Fig. 3.

II b) Spectral coverage and resolution

In the standard configuration one CCD frame covers approximately 900 Å. The orders are more packed and with a broader wavelength overlapping in

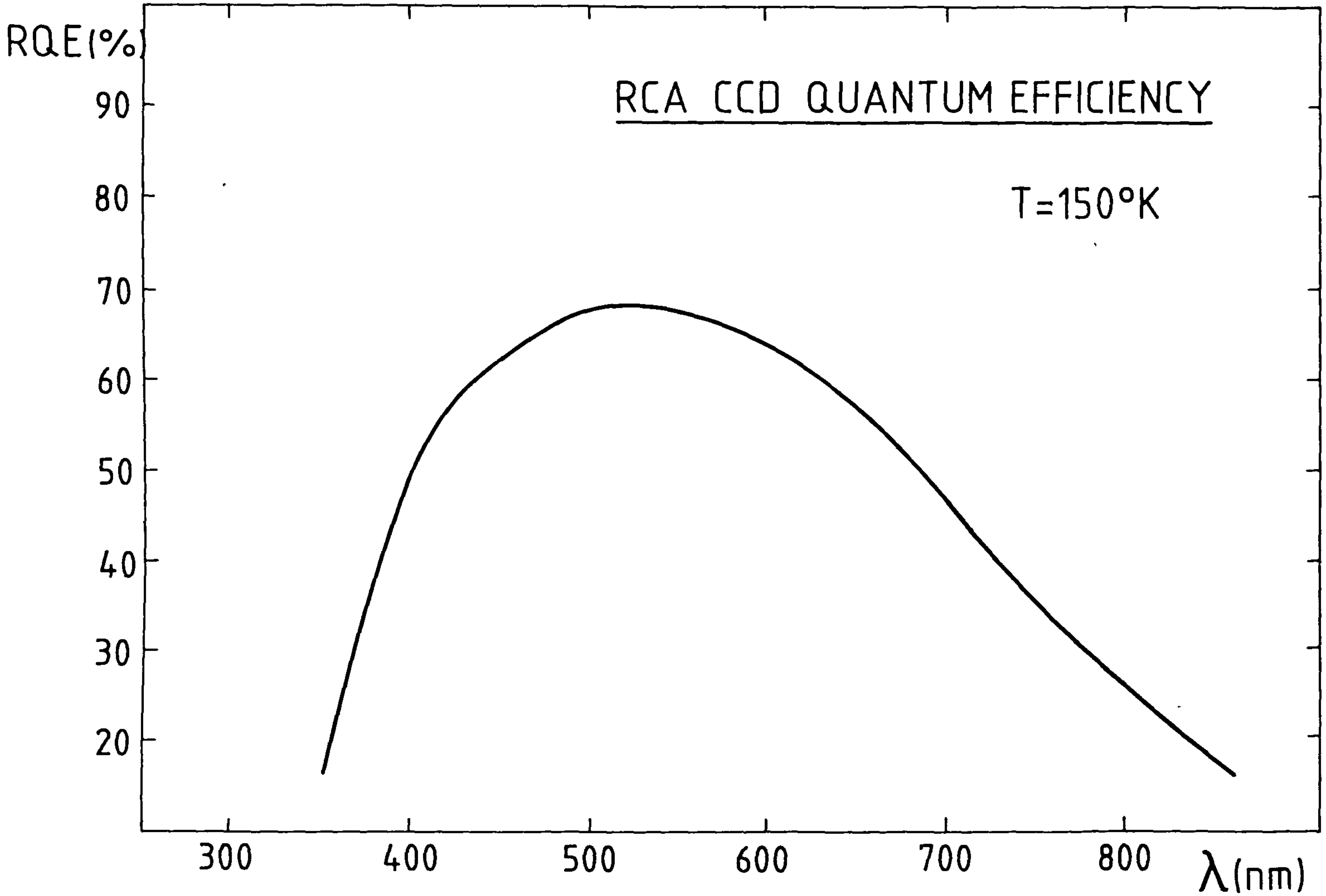

Fig. 2: Quantum efficiency curve of the CCD as measured in the ESO detector lab.

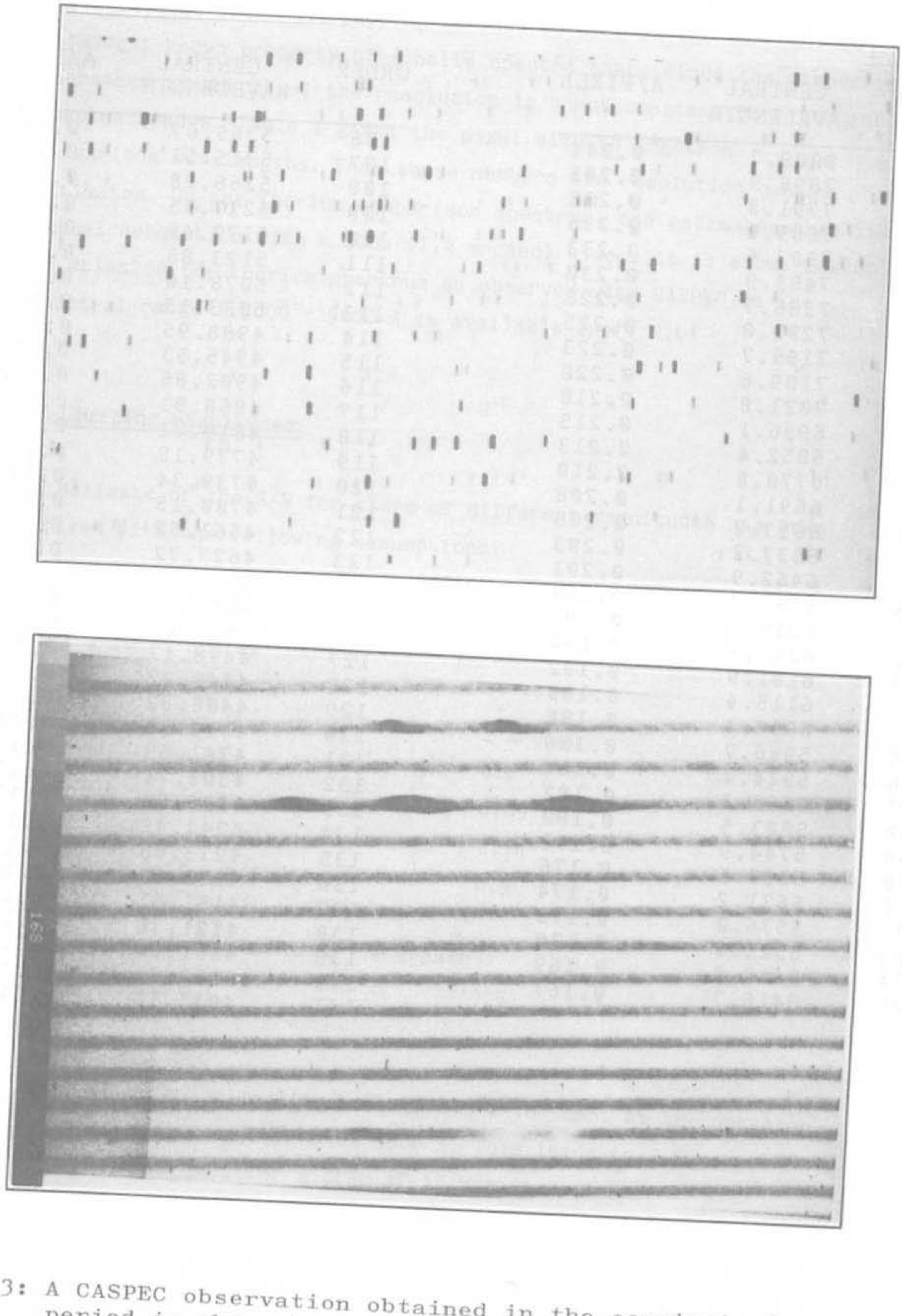

Fig. 3: A CASPEC observation obtained in the commissioning period is shown together with the corresponding exposure of the thorium lamp. The object is the nucleus of the galaxy NGC 1808, the exposure time 60 m, the central wavelength 6300 Å, the slit dimension 2.8 x 6 arcsec. Note the velocity gradient in the emission lines of Hα, [NII] and [SII], the broad Na I absorption doublet and the frequency of cosmic ray events.

TABLE I

ORDER	CENTRAL WAVELENGTH	A/PIXEL
71	8009.7	0.244
72	7898.9	0.241
73	7791.0	0.238
74	7685.9	0.236
75	7583.6	0.233
76	7483.9	0.230
77	7386.7	0.228
78	7292.0	0.225
79	7199.7	0.223
80	7109.6	0.220
81	7021.8	0.218
82	6936.1	0.215
83	6852.4	0.213
84	6770.8	0.210
85	6691.1	0.208
86	6613.2	0.205
87	6537.2	0.203
88	6462.9	0.201
89	6390.2	0.199
90	6319.2	0.196
91	6249.8	0.194
92	6181.9	0.192
93	6115.4	0.190
94	6050.4	0.188
95	5986.7	0.186
96	5924.4	0.184
97	5863.3	0.182
98	5803.5	0.180
99	5744.9	0.178
100	5687.5	0.176
101	5631.2	0.174
102	5576.0	0.172
103	5521.9	0.170
104	5468.8	0.169
105	5416.7	0.167
106	5365.67	0.165
107	5315.51	0.163
108	5266.28	0.162
109	5217.95	0.160
110	5170.49	0.159
111	5123.88	0.157
112	5078.10	0.156
113	5033.13	0.154
114	4988.95	0.153
115	4945.53	0.151
116	4902.86	0.150
117	4860.93	0.148
118	4819.71	0.147
119	4779.18	0.146
120	4739.34	0.144
121	4700.15	0.143
122	4661.62	0.142
123	4623.72	0.141
124	4586.45	0.140
125	4549.77	0.139
126	4513.68	0.138
127	4478.17	0.136
128	4443.22	0.135
129	4408.82	0.134
130	4374.95	0.134
131	4341.59	0.133
132	4308.74	0.132
133	4276.38	0.131
134	4244.49	0.130
135	4213.06	0.129
136	4182.08	0.128
137	4151.51	0.128
138	4121.36	0.127
139	4091.60	0.126
140	4062.21	0.126
141	4033.18	0.125

the blue, but order overlapping is insured also in the far red. It is a well-known property of échelle spectra that, since the dispersion increases in the blue, the resolution is about constant over the entire spectral range. Table I gives the pixel size in Angstrom at various wavelengths. From these numbers the resolution can be estimated. On the Thorium comparison spectrum, one estimates that the actual resolution with a 200μ (1.4 arcsec) wide slit is about 20.000. An atlas of the thorium spectrum as observed with CASPEC in the spectral range λλ3600 - 9000 Å is available (ref. 2).

II c) Limiting magnitudes

An estimate of the S/N for stars of different magnitudes has been derived with the following assumptions:

Flux above the atmosphere at λ = 5000 Å for a star of 15 magnitude = 3.7×10^{-15} erg cm^{-2} Å^{-1} s^{-1}

A uniform seeing disc of	2 arcsec
Atmosphere losses	0.8
2 reflections in the telescope	0.85^2
CASPEC overall efficiency	0.14
CCD quantum eff. at 5500A	0.4
Loss due to the use of a 1.2 arcsec wide slit	0,5

At the 3.6 m the collecting area is 8.2×10^4 cm^2. At the detector, 1 pixel corresponds to 0.17 Å at 5500 Å. This leads to 0.1 electrons/pixel sec, for a star of 15 magnitude.

As sources of noise we consider the photon statistics for the signal, a read-out noise of the CCD of 50 elect./pixel, and the shot noise for an optimal pre-flash exposure corresponding to 2500 electrons. The S/N for different stars as a function of exposure times are shown in Fig. 4.

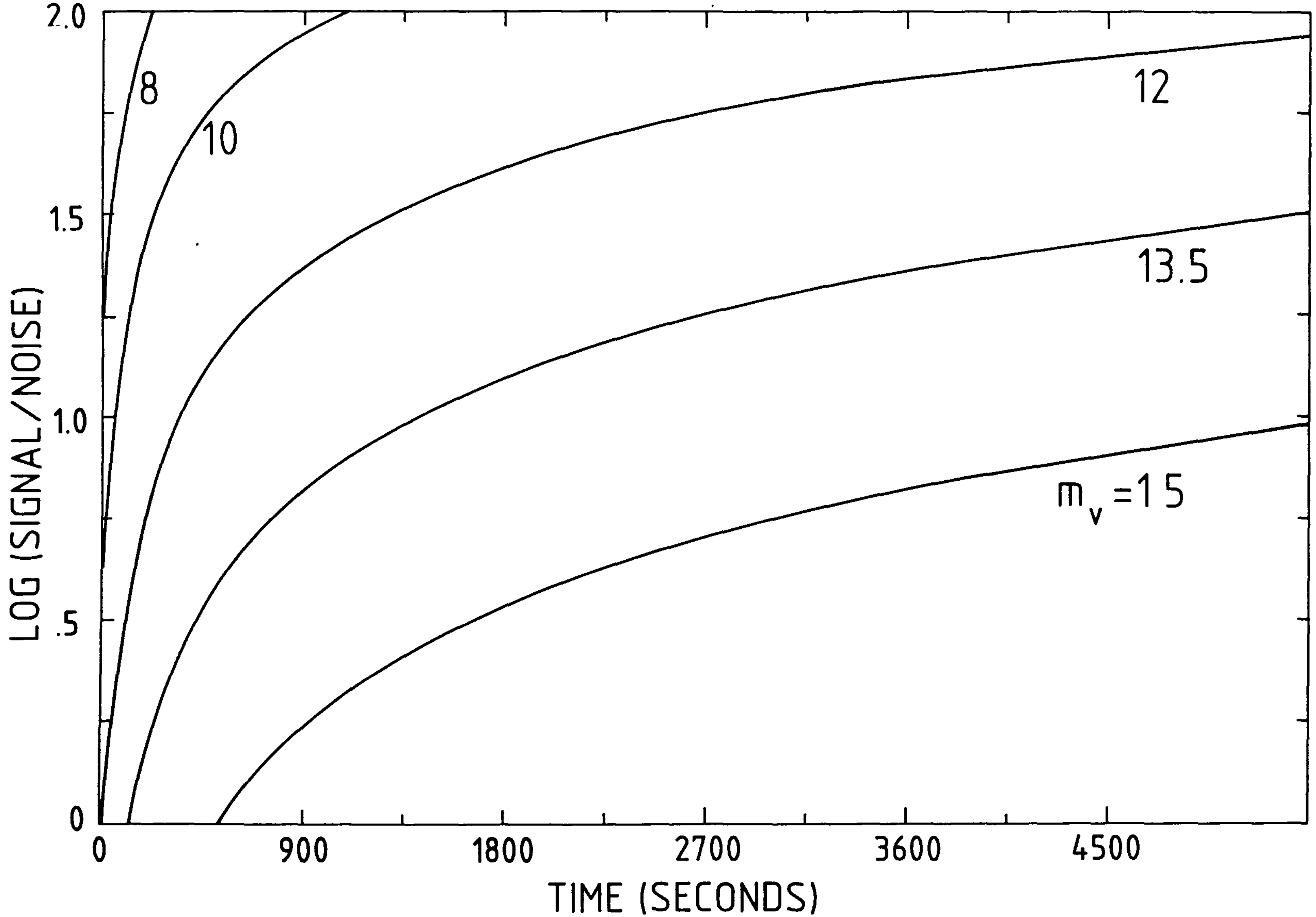

Fig. 4: The expected S/N ratios per pixel at 5500 Å as a function of exposure time for stars of different magnitudes. Basic assumptions are given in the text.

The data are indicative only. The results are strongly seeing dependent, and the quantum efficiency varies in different chips. The accuracy of the flat fielding of the CCD may in fact be the limiting factor in many observations. The relative weight of the noise sources versus the signal level per pixel for a given exposure time is illustrated in Fig. 5. For a typical exposure of 1 hr, the CCD intrinsic noise dominates other sources of error for stars fainter than 14th magnitude. It is important to guide accurately the spectra because trailing will tend to lower the S/N ratio.

Fig. 6 finally gives the curve of relative efficiency of the spectrograph with the RCA CCD detector.

II d) Zeeman analyser

CASPEC mounts a Zeeman analyser which consists of an achromatic $\lambda/4$ plate and a Wollaston prism (ref. 1). The analyser can be inserted in the optical beam by entering the "Rear viewer" option 2 in the observation form (Fig. 9). The system includes compensation for the change of focus.

The device has been tested with a laboratory source (the Hg 5461 A emission line) and at the telescope and has worked smoothly. However, note that with the 31.6 lines/mm grating, the split orders overlap shorter of about 5500 A. By using the 52 lines/mm échelle (III e) it is possible to observe with the ZA to about λ 4500 A. Only a few observations were obtained with the Zeemann analyser in the commissioning period. The limiting magnitude for a well-exposed continuum spectrum is about 10.

III a) Setting an exposure

The control program of CASPEC is entered by logging in the program CASP on the instrument console in the control room. Setting up, maintenance and actual observing with the spectrograph can then be controlled via a number of self-explanatory "menus" based on softkeys and by filling forms.

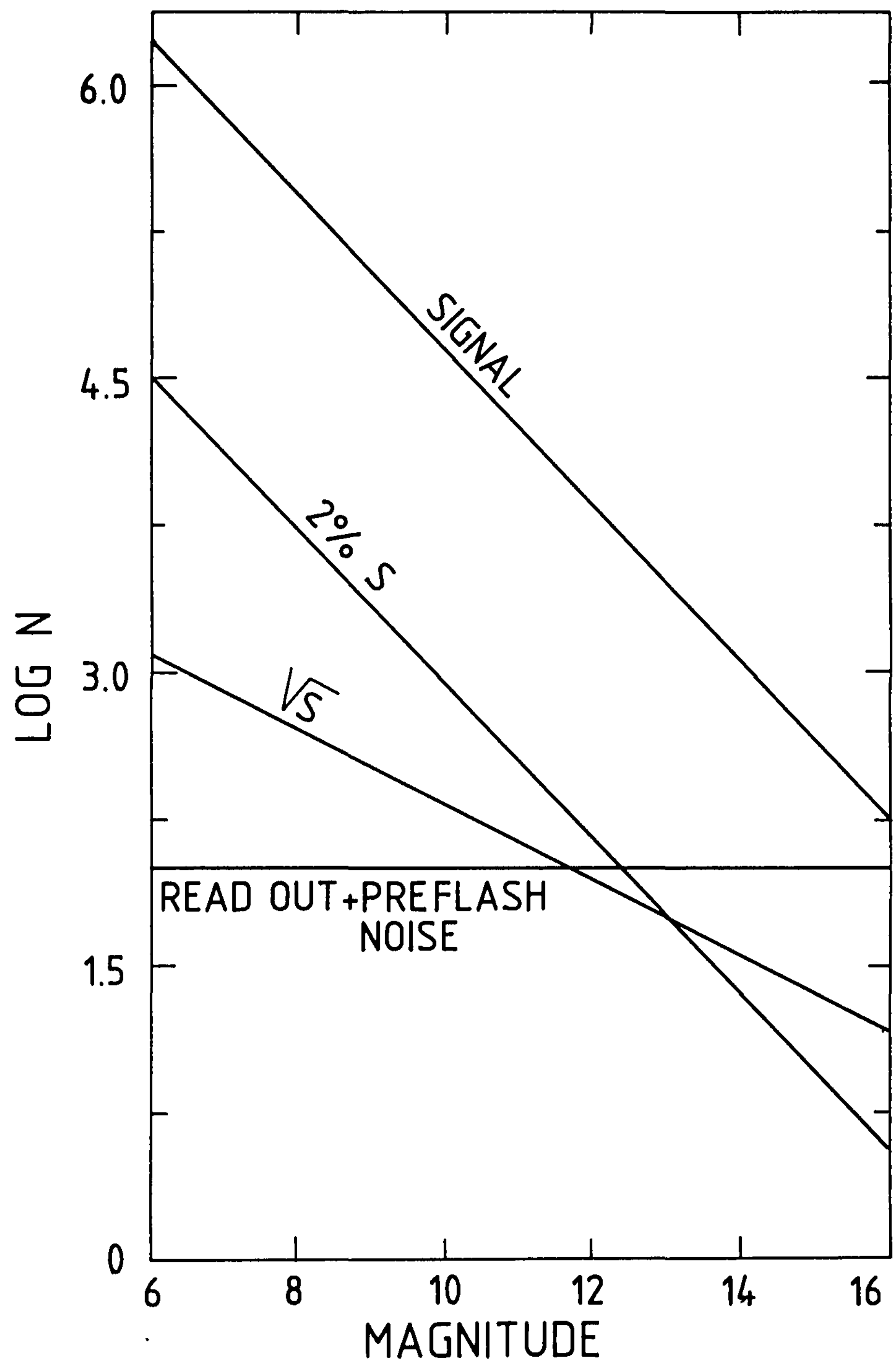

Fig. 5: Expected signal and noise sources per pixel in a 1 hour exposure at 5500 Å.

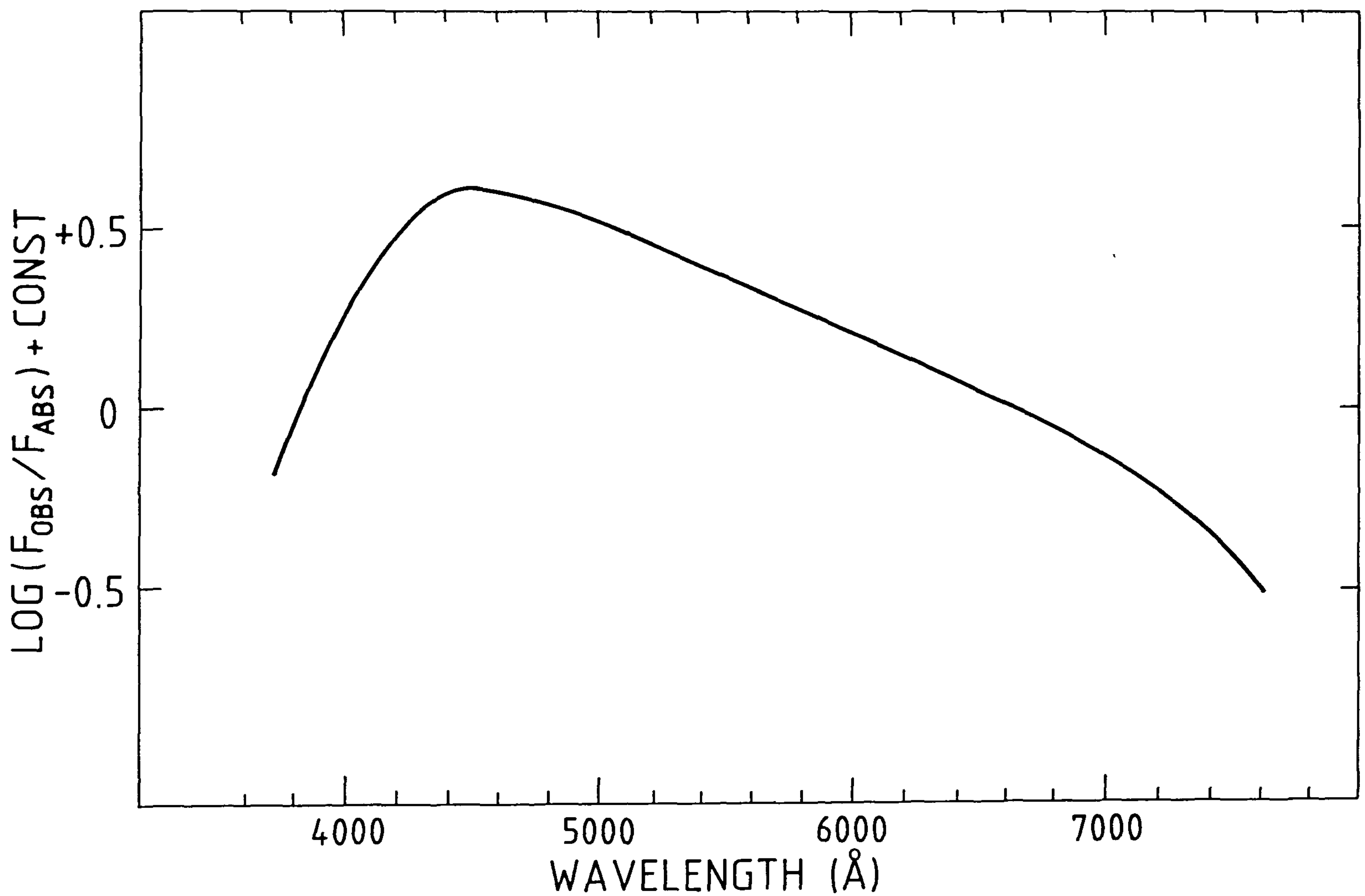

Fig. 6: Relative efficiency of CASPEC. The curve was obtained by D. Ponz comparing the known energy distribution of the star ηHyd with four CASPEC frames.

Details of the CASPEC control software are to be found in ref. 1. The most common menus and forms which the user has to deal with are shown in Figs. 7-17. Note that in most cases a HELP softkey is available. If you require a printed output of the operations and forms used in the night, enter the LOG softkey in the menu shown in Fig. 7.

III b) Setting up the CCD binning and bias light

The on-chip summation of pixels in x or y direction (binning) and the pre-flashing are the two CCD parameters at the observer's discretion. The justifications for the use of these options are given in pgph. IV b). These parameters can be set by entering the CCD softkey in the menu of Fig. 7. The successive steps are illustrated in Fig. 13-17.

The CCD has to be initialized by entering the corresponding softkey any time a modification of the parameters has been entered.

III c) Calibration exposures

The minimum set of calibration exposures which should accompany the observations consists of a set of dark exposures, a wavelength calibration exposure and a flat field exposure.

Dark exposures on the CCD

Several 1^s dark exposures can be averaged and substracted from the actual observations to take out the electronic bias (200 ADU) and the optional pre-flash exposure.

If the voltages and the temperature of the CCD are kept constant, a dark exposure sequence per run should be sufficient. At least one long dark exposure (~ 1 hrs) is also useful to monitor the dark noise of the CCD and any exposure dependent feature.

Wavelength calibration exposure

A thorium lamp is used to obtain the wavelength calibration. Cautious observers should take a comparison spectrum at every telescope setting, even if so far we have not experienced any shift at different spectrograph orientations (ref. 1 and experiences from the test run). The accuracy of radial velocity measurements has been found to be better than 2 km/sec from observations of standard stars (ref. 5).

Flat fielding exposures

An incandescence lamp in the spectrograph provides the flat field exposure for the CCD. In the data reduction phase, once the background has been substracted, the object exposure will have to be divided by the flat field to correct for CCD inhomogeneities and fringing effects. Fringes are present at $\lambda > 5000$ Å and they introduce variations in the response as high as 30% at red wavelengths (ref. 3).

It is recommended that the flat field is taken prior to the thorium lamp.

Since flat field exposure makes use of neutral density filters, this sequence avoids the ND to be in the optical path of the TV camera which looks at the slit in the preparation of the following star exposure. It is also possible to remove the filter by reinitializing the functions (see the appropriate softkey in the menu of Fig. 8).

To ensure a good overlap it is recommended to take the flat field exposure with a longer slit than the actual spectrum, if this is permitted by the order separation.

In the present standard configuration (slit width 300μ, cross disperser 300 lines/mm, échelle 31.6 lines/mm, RCA back illuminated chip) the following exposure times have been found to give well exposed thorium exposures and flat fields of maximum intensity around 10000 ADU:

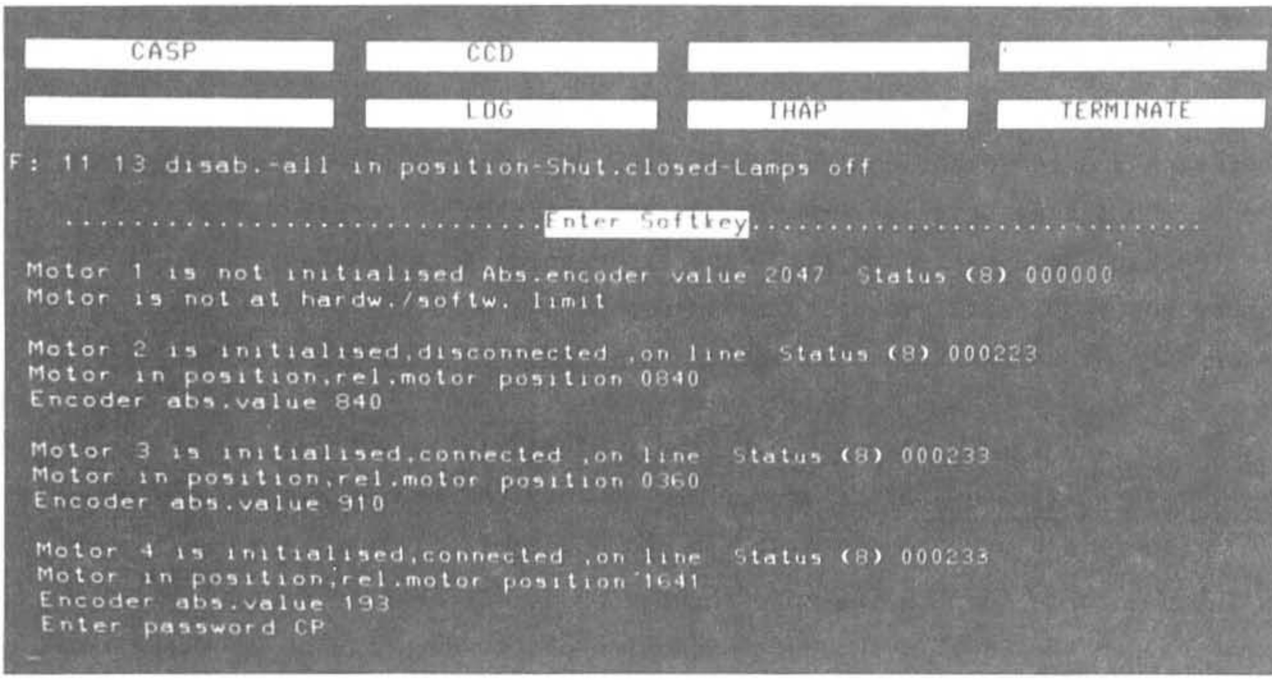
CASP
CCD
LOG
IHAP
TERMINATE
F: 11 13 disab.-all in position-Shut.closed-Lamps off
Enter Softkey
Motor 1 is not initialised Abs.encoder value 2047 Status (8) 000000
Motor is not at hardw./softw. limit
Motor 2 is initialised,disconnected ,on line Status (8) 000223
Motor in position,rel.motor position 0840
Encoder abs.value 840
Motor 3 is initialised,connected ,on line Status (8) 000233
Motor in position,rel.motor position 0360
Encoder abs.value 910
Motor 4 is initialised,connected ,on line Status (8) 000233
Motor in position,rel.motor position 1641
Encoder abs.value 193
Enter password CP

Fig. 7

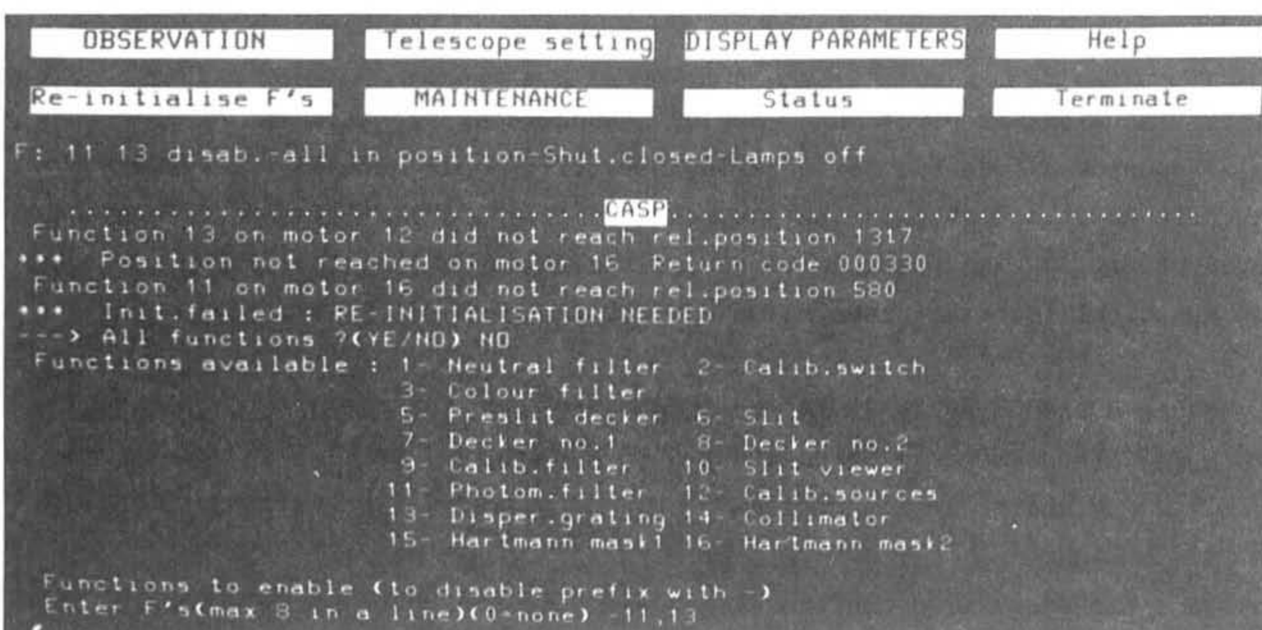
OBSERVATION
Telescope setting
DISPLAY PARAMETERS
Help
Re-initialise F's
MAINTENANCE
Status
Terminate
F: 11 13 disab.-all in position-Shut.closed-Lamps off
CASP
Function 13 on motor 12 did not reach rel.position 1317
*** Position not reached on motor 16 Return code 000330
Function 11 on motor 16 did not reach rel.position 580
*** Init.failed : RE-INITIALISATION NEEDED
---> All functions ?(YE/NO) NO
Functions available : 1- Neutral filter 2- Calib.switch
3- Colour filter
5- Preslit decker 6- Slit
7- Decker no.1 8- Decker no.2
9- Calib.filter 10- Slit viewer
11- Photom.filter 12- Calib.sources
13- Disper.grating 14- Collimator
15- Hartmann mask1 16- Hartmann mask2
Functions to enable (to disable prefix with -)
Enter F's(max 8 in a line)(0=none) -11,13

Fig. 8

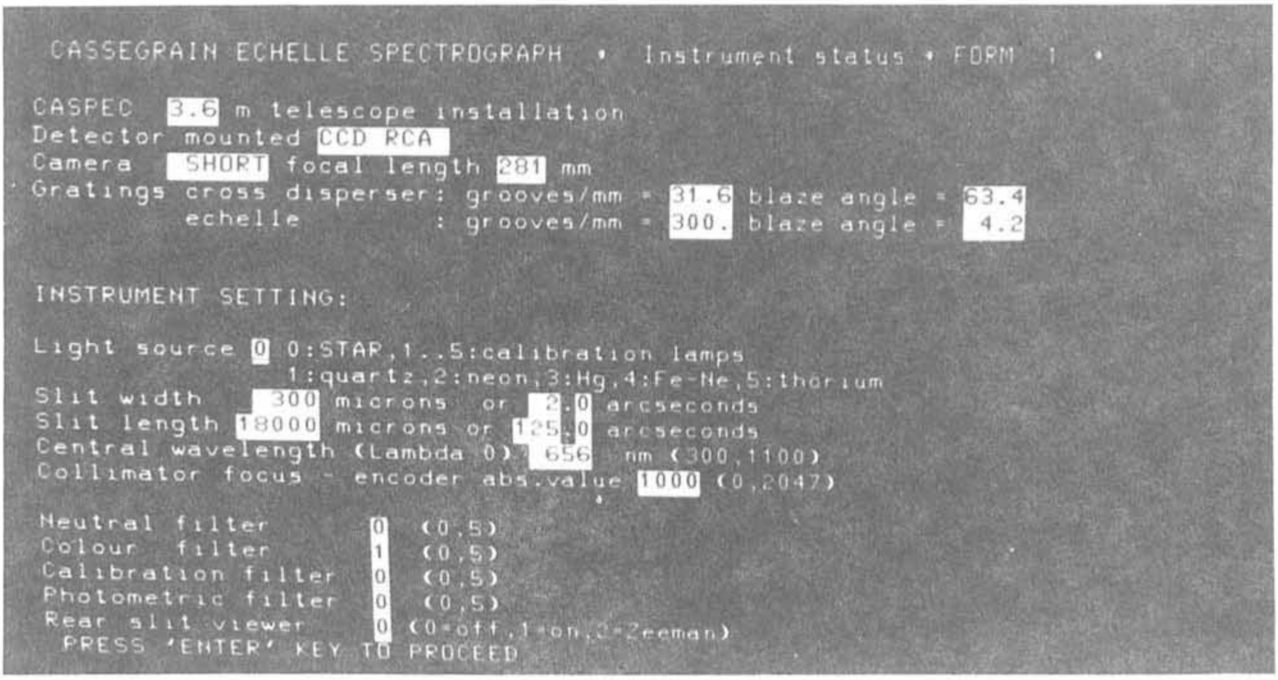

Fig. 9

Figs. 7, 8, 9: Initial options of the CASPEC control program are shown in Fig. 7. By entering CASP, the menu of Fig. 8 gives the choice between a check on the status of the spectrograph (Fig. 9), maintenance operations and setting up of the observations.

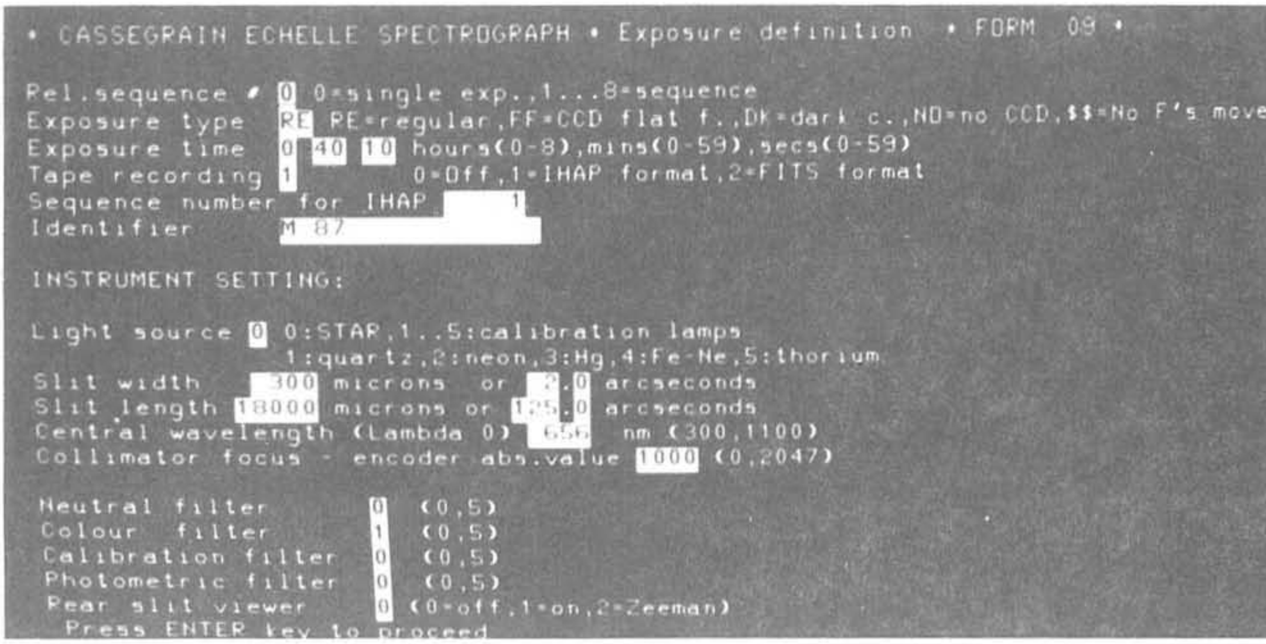

Fig. 10: This form, to be completed by the observer, defines the parameters of the observation. Most of it is self-explanatory but it is to be remarked:

- In the exposure type, FF is just a CCD flat field with no light going through the spectrograph
- Default value for type recording is IHAP format
- It is sufficient to enter the dimensions of the slit in μ (at the Cassegrain focus of the 3.6 m 100μ = 0.72 arcsec)
- Collimator focus has not to be modified by the observer
- Characteristic of the neutral density and colour filter are given in form 11 (Fig. 11).

Note that the parameters of the CCD, of the spectrograph and of the telescope are fed to the file header and can be printed with the IHAP commands shown in Table 2.

TABLE II: CONTENT OF THE CASPEC FILE HEADERS

```
DLIST,#1,LONG

#0001          NGC 1808
*
IDENTIFIER              * NGC 1808
CREATED BY SYSTEM       * GENERAL
SEQUENCE #              *  00003
RIGHT ASCENSION         *  05 07 10
DECLINATION             * -37 26 21
AIRMASS                 *      .000
CREATED YEAR  DAY       * 0000  0000
CREATED TIME            *  00 00 00
MEASUREMENT START       *  03 48 55
MEASUREMENT END         *  04 49 10
SCAN METHOD             * EDGE
FILE CONTENTS           * IMAGE DATA
DATA FORMAT             * INTEGER 16 BITS
X-START  X-END          *     1.000    337.000
Y-START  Y-END          *     1.000    520.000
X-STEP  Y-STEP          *     1.000      1.000
#PIXELS-X  #LINES-Y     *  00337      00520
SCALE-X  SCALE-Y        * NOT-SET    NOT-SET
THRESHOLD LCUT HCUT     * NOT-SET    NOT-SET
#WORDS  DRIVE           * 175240.0    00000
#BLKS-DATA #BLKS-INF*  01370      00000
BLKST-DATA BLKST-INF*  00000      16147
USER INTEGER            *  00009      03615
USER FLOAT              *      .000       .000
WCOMMENT,#1
 #0001
04 :49 :37 <01> $DETTYPE 'CCD'
04 :49 :37 <02> $DETNAME 'RCA SETUP CHIP'
04 :49 :37 <03> $EXPTYP 'RE'
04 :49 :38 <04> $DETSTAT 'HHI +04.41 HLO -04.63 VHI -00.01 VLO -07.17'
04 :49 :39 <05> $DETSTAT 'RHI +04.89 RLO -06.79 RD +12.05 OD +12.19'
04 :49 :40 <06> $DETMTEMP  152.1 DETDTEMP    0.0
04 :49 :40 <07> $DETBLTIM   .05
WICOMMENT,#1
*
 #0001
*
$INSTRUME 'CASPEC 3.6 M'
$BLAZANGL 63.4 GRATFREQ  .3125E-04 CAMRLEN  .2810E+005
$FLTRNR 0 NDFLTR  0. 0 SLITWDT  .4000E-03 SLITLEN  .8000E-03
$COLLPOS 1000.0 WAVELENG  .6300E-06 HARTPOS 0 LAMPNR 0
```

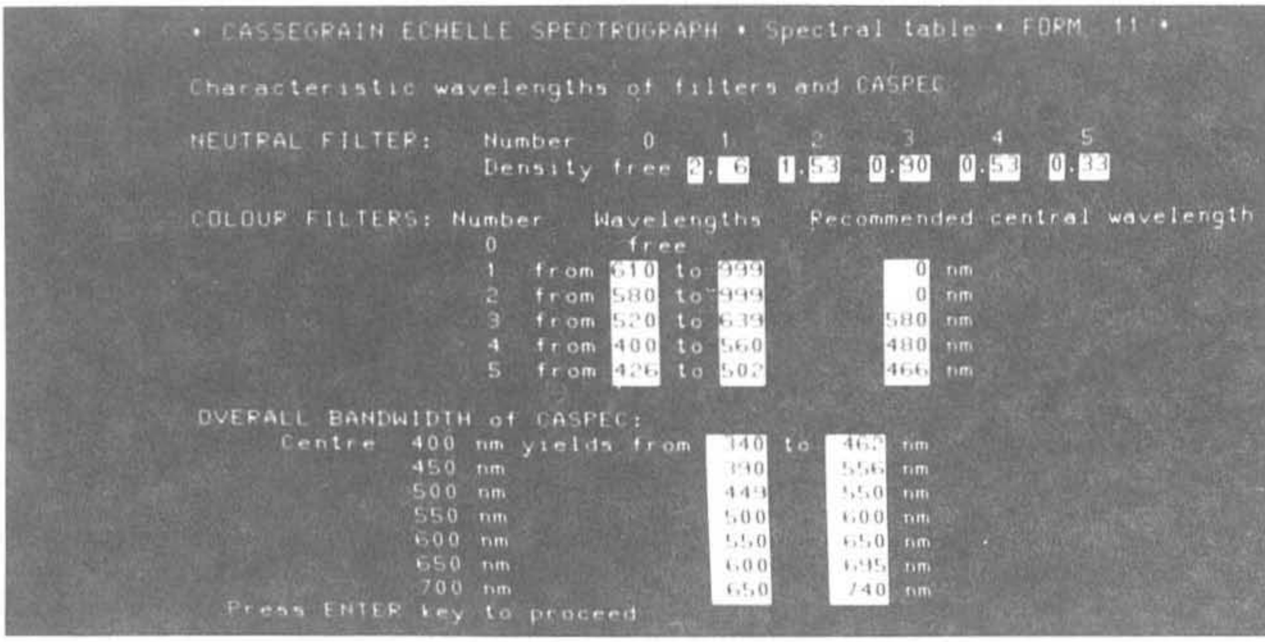

Fig. 11: Filter definition and indicative bandwidths of CASPEC.

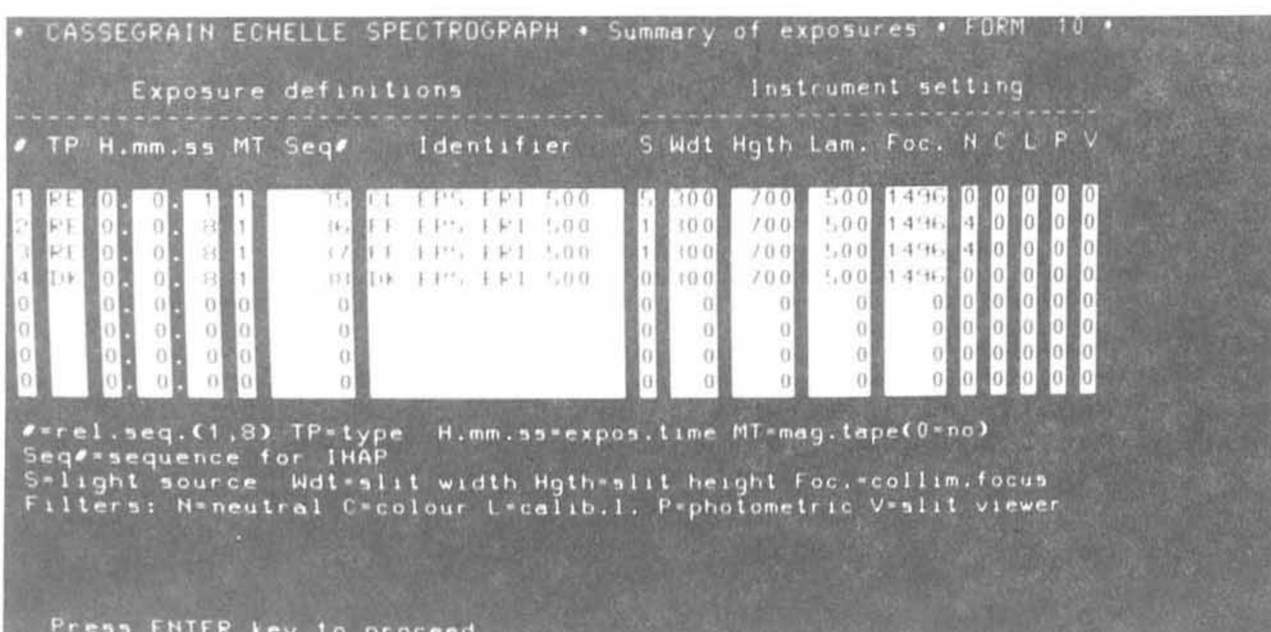

Fig. 12: This form monitors the compilation of a sequence of exposures which is entered through form 9.

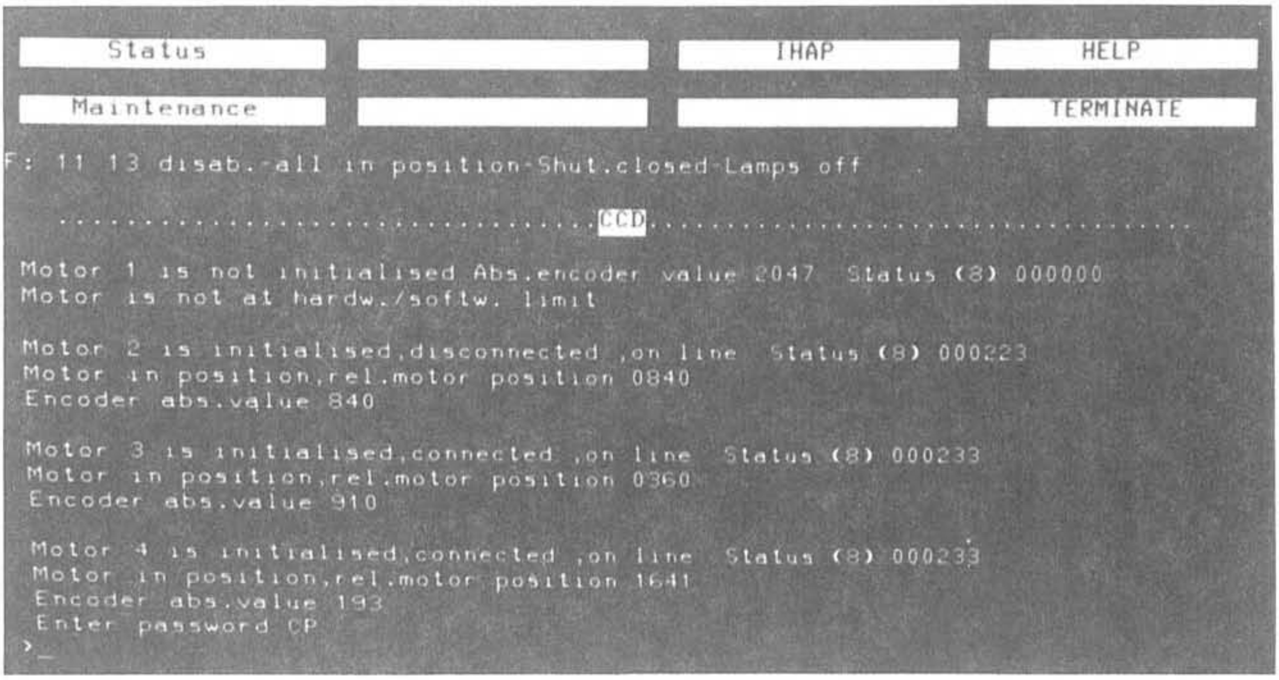

Fig. 13: Modification of binning and preflash exposure of the CCD is possible by entering the Maintenance softkey.

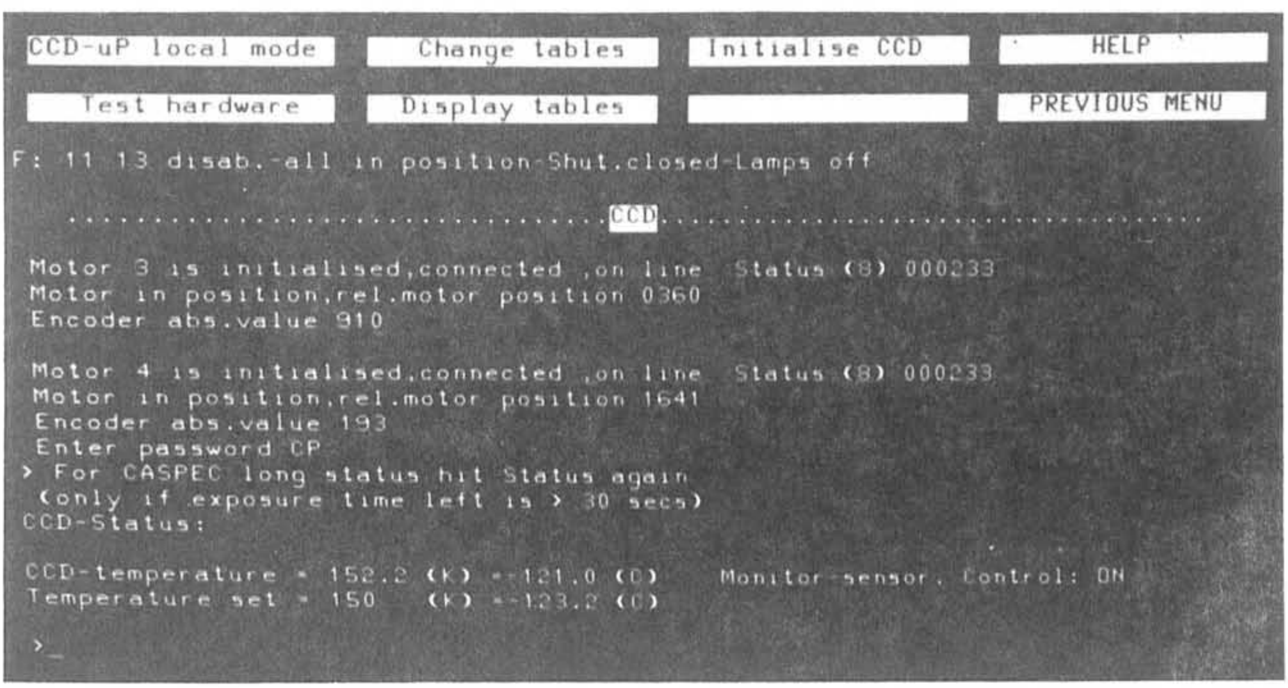

Fig. 14: Within CCD Maintenance, the "change tables" softkey has to be entered. Initialize CCD after any modification/s.

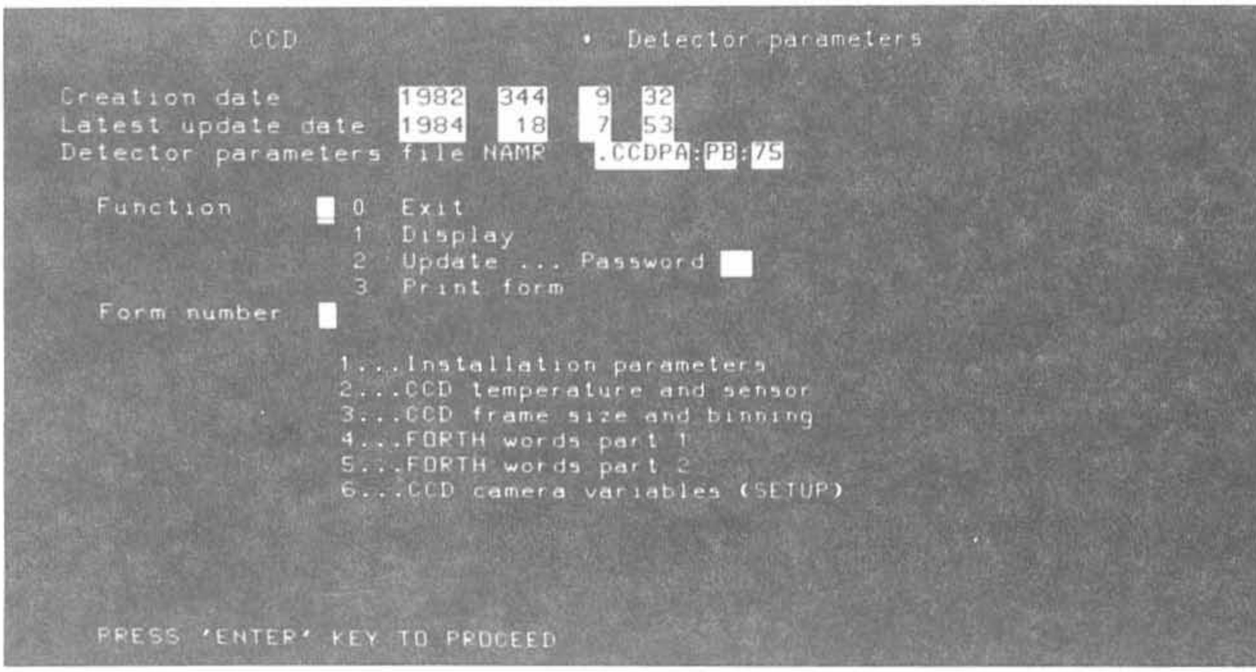

Fig. 15: The password for updating the CCD frame (no. 6) is PB.

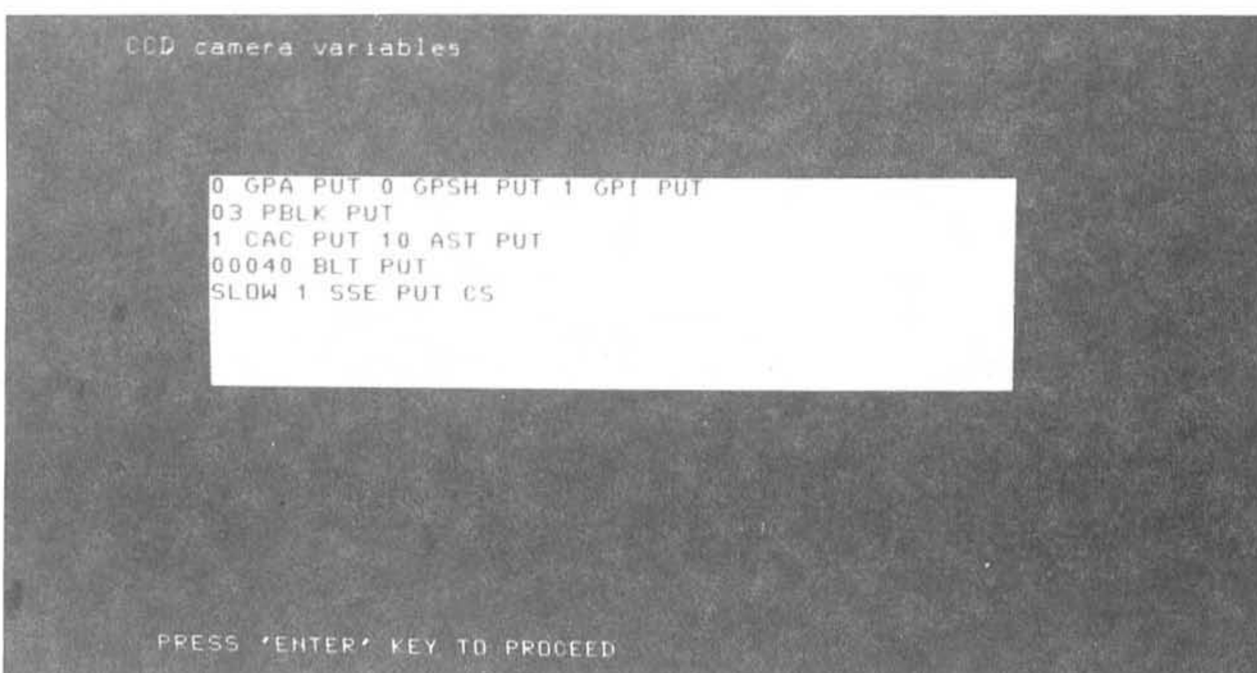

Fig. 16: BLT PUT is the exposure time for the CCD preflash. Note that 40 ms as given in the form corresponds to ~70 ADU per pixel.

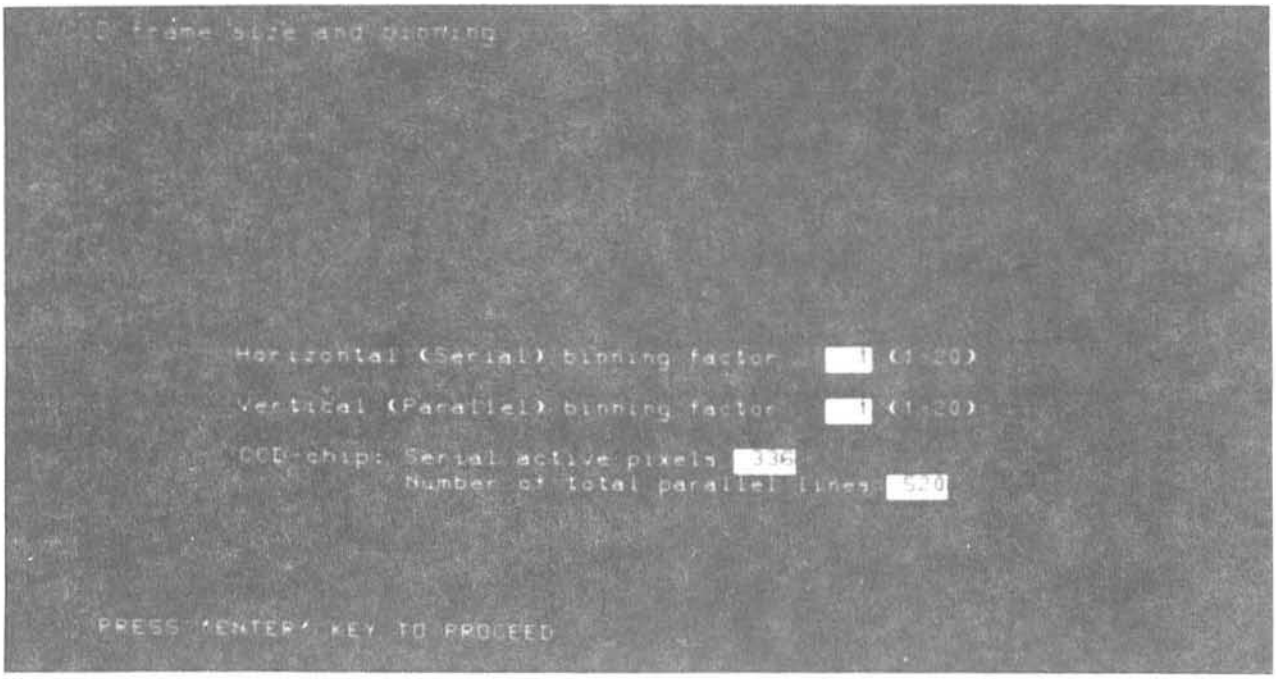

Fig. 17: This form is used to enter the binning factor. Vertical binning is along the large dimension of the CCD, that is the dispersion direction in the standard configuration.

λ centr	Thorium lamp (sec)	Internal quartz lamp (sec)
4300	10	45 + ND5 + blue filter
5000	8	20 + ND3
6000	10	20 + ND3
7000*	30	15 + ND3
8000*	60	3 + ND5
9000*	60	3 + ND5

Note that these values may change if the present lamp is replaced.

* Color filter no. 1 has to be inserted to avoid second order contamination. These orders include some bright Ar line which are saturated in the exposure times needed to reveal the other lines.

In the long slit mode (pgph. III d)), these exposure times have been found to be appropriate (no-binning case).

H_α region isolated by means of a filter of 50-70% transmission:

thorium: 20^s Flat field 10^s + ND3

[O III] region, 50-70% transmission

thorium: 10^s Flat field 20^s + ND3

III d) Long slit mode

In this mode, the cross disperser is replaced by a flat mirror and a spectral region is isolated by means interferential filters. If the filter is narrower than an échelle order, a long slit can be used without order overlapping. The maximum slit length is 2 cm or 144 arc sec at the Cassegrain focus of the 3.6 m telescope. Fig. 18 shows the format of a thorium lamp exposure and the spectrum of a planetary nebula.

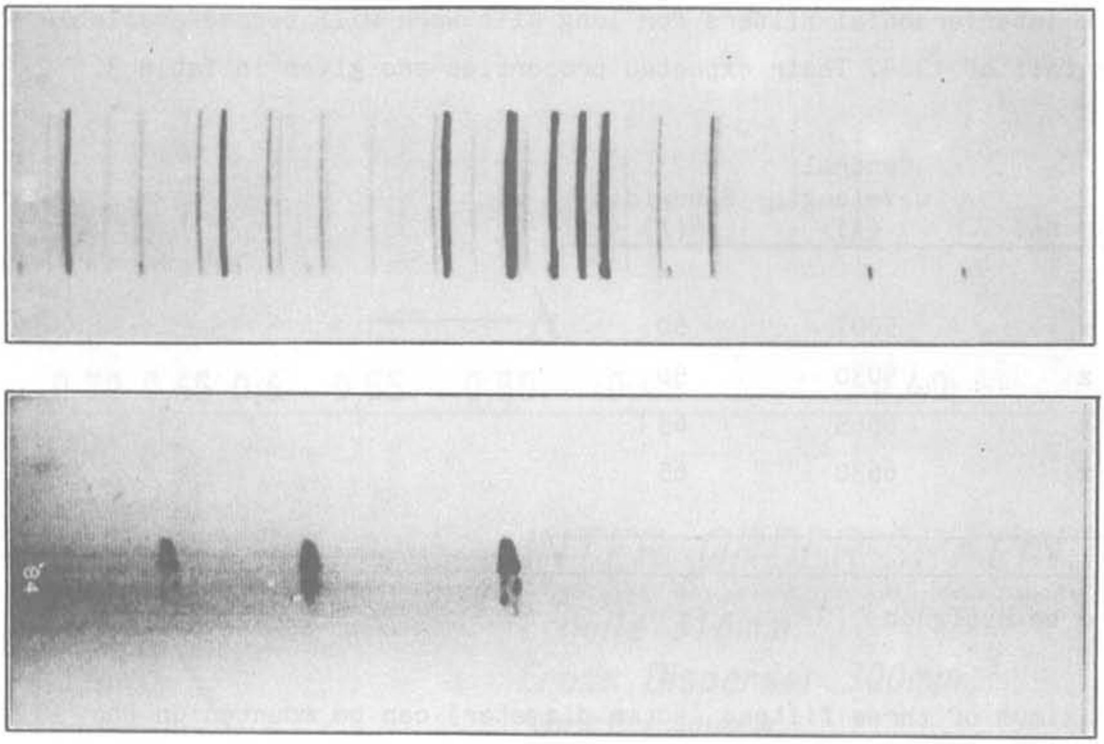

Fig. 18: A 15 m exposure of the planetary nebula NGC 2818 in the long slit mode of the spectrograph is shown together with the corresponding thorium lamp exposure. An Hα filter was used in combination with the 31.6 lines/mm échelle grating. Note that the CCD was binned horizontally.

Four interferential filters for long slit work will become available in the fall of 1984. Their expected properties are given in Table 3.

ESO No.	Central wavelength (Å)	Bandwidth (Å)
x	5007	50
x	5030	50
x	6565	65
x	6630	65

* to be assigned

A maximum of three filters (40 mm diameter) can be mounted on the spectrograph filter wheel before the beginning of an observing run. Note that in this mode it is not possible to guide on the slit, and offset guiding has to be used.

A limited experience on this mode has been obtained during the commissioning period by inserting manually ESO interferential filters in size 1 or 2 inches in the optical path of the spectrograph. The ESO filters 354(λ6563Å), 360(λ5015Å) and 183(λ5007) have been used. The speed of the long slit mode with these filters appears somewhat lower than in the normal mode, and the amount of scattered light is greater.

As a general remark, horizontal binning of the CCD should be used whenever very high spatial resolution in very good seeing condition is not required. Since 1 pixel corresponds to 0.7 arc sec in the direction normal to the dispersion, binning of the CCD will result in a better S/N ratio (see IV b)).

III e) The 52 lines/mm Echelle

The separation between the orders is uncomfortably short with the 31.6 lines/mm échelle and the short camera in the blue spectral region (see Fig. 19).

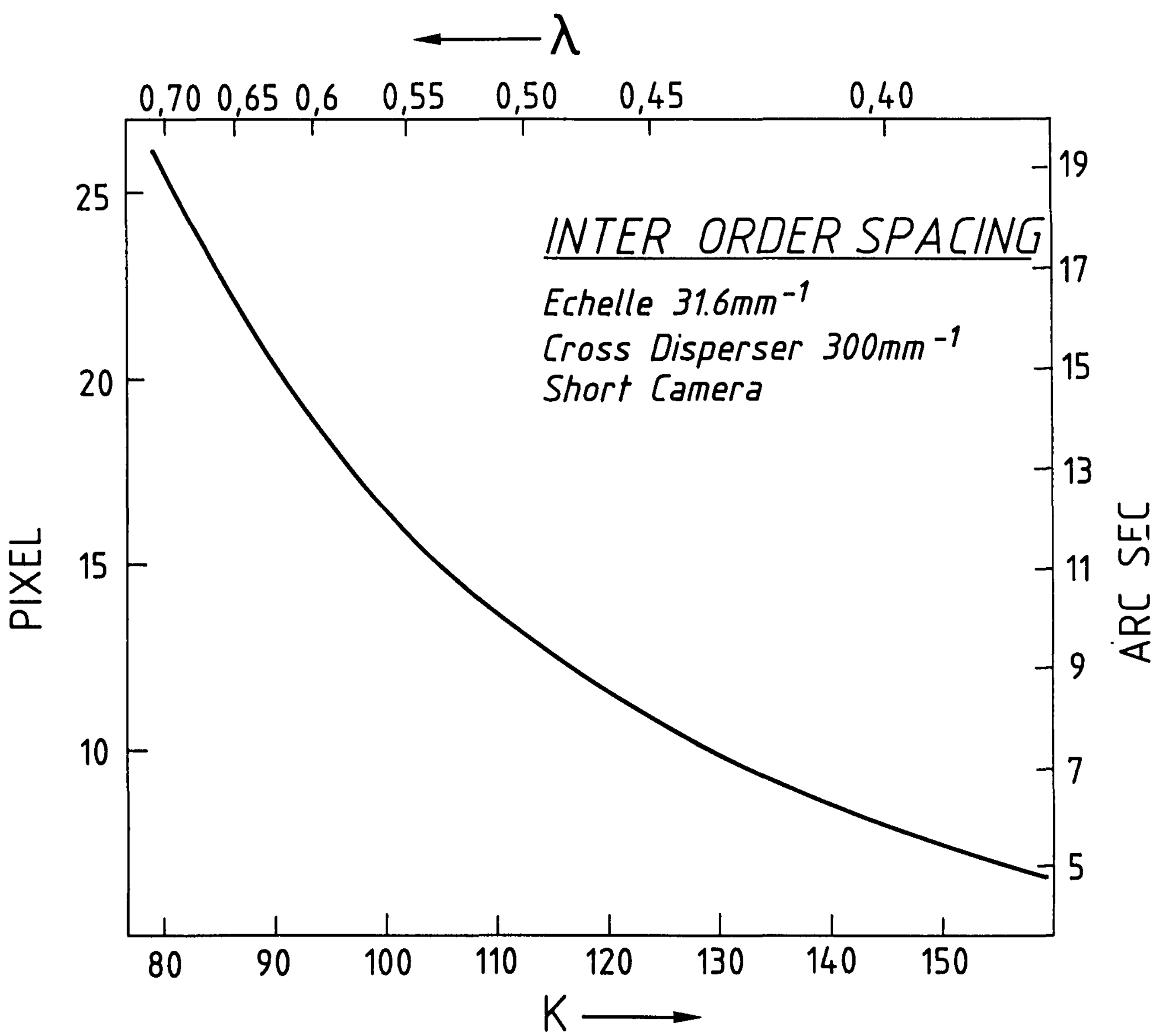

Fig. 19: Interorder spacing on the CCD in pixels and arcsec as a function of wavelength.

An alternative échelle grating (52 lines/mm) has become available in the summer of 1984 and it is recommended for λ < 4200Å and if larger order spacing is needed. The actual interorder separations at a given λ can be obtained from the values in Fig. 19 by multiplying the values by 1.6. Full spectral coverage is achieved as far as λ = 5000Å.

III f) Other detectors

The small size of the CCD detector has been the driving factor in the choice of the optical configuration of the spectrograph (ref. 1). Should a larger detector become available, a different solution and possibly also the long camera of the spectrograph could be implemented. ESO is in particular trying to acquire a photon-counting detector which should give considerable advantage over the CCD at least in the UV region.

As a more immediate development, we expect to test low read-out noise G.E.C. CCD's on the spectrograph during 1984.

IV Miscellaneous comments and advice

IV a) The choice of the slit length and width, slit orientation

CASPEC provides some capabilities to do two-dimensional spectroscopy. One RCA CCD pixel corresponds to 0.7 " at the slit. Order overlapping sets the limit to the length of the slit which can be used. The distance from contiguous orders in the standard configuration is given in Fig. 19.

It is recommended to keep sufficient space between orders to permit:

a) tracings of the orders in the automatic data reduction program

b) accurate monitoring of the CCD background, which is essential for an accurate flat fielding of the data.

The following table lists the recommended upper limits for the slit lengths at various wavelengths (31.6 lines/mm échelle). Multiply by 1.6

to have the corresponding values for the 52 lines/mm échelle.

$\lambda_{central}$	4500	5500	6500	7500
max. slit length (μ)	400	700	1000	1300
" (arcsec)	2.9	5	7.2	9.4

If a longer slit is required, the long slit mode (pgph. IV d)) will have to be used.

The deckers which define the slit length are not visible when the TV camera is used to center the targets on the aperture. The center of the slit is defined by two black arrows.

As for the choice of the slit width, a trade-off is necessary between maximum light input and resolution. One pixel at the detector corresponds to 170 μ at the focal plane (1.22 arc sec at the 3.6 m). There is no gain in using a narrower slit, and the resolution degrades only slowly up to apertures whose projection is less than two pixel on the detector. This permits high efficiency work at the highest resolution even with seeing of the order of 2 arc sec.

When using CASPEC at the 3.6 m, it is possible to rotate the spectrograph to change the orientation of the slit from the E-W direction. The operation can be done remotely from the control room.

It is recommended to limit the rotation to a maximum of ± 90° and to check carefully in the cage that wire connections are not obstructing the movement.

IV b) Binning and preflashing the CCD, cosmic ray frequency

Binning

Binning of the CCD in the direction of the dispersion (vertically) or perpendicular to it (horizontally) is an option open to the user. It is found useful when the main source of noise is the read-out characteristics of the CCD (see Fig. 5); in that case it has to be preferred to rebinning of the spectrum in data reduction phase. Horizontal binning cannot be used in the standard configuration for wavelengths shorter of 6000A because the order separation becomes too small.

Preflashing has been found useful to improve the charge transfer efficiency of the RCA CCD. A level of about 100 ADU (1500 photoelectrons) strongly reduces the "tail" which a point-like source over a dark background produces in the horizontal direction (ref. 1). This procedure obviously introduces some additional noise and being a compromise solution, very much depends on the properties and set-up of the CCD chip which is in use. The effect is recognized at best in cosmic ray events and the user might judge for himself the need for the preflashing in a long, dark exposure of the beginning of the run.

The detection of cosmic rays in astronomical CCD has been reported by several observers (ref. 6). They appear as point like (1-2 pixels) events with typical energies up to a few hundred electrons. Fig. 20 is a histogram of the detections in a 30 m dark exposure. The frequency that we derive (0.07 events/sec, cm^2) and the typical energy (400 e-) is very close to values quoted by other authors for the thinned RCA CCD's.

The events can be identified and removed by comparing different exposures or using a software filter. However, removal of the low energy events from a spectrum is hardly 100% effective and this limits the integration time to something like two hours. The value is strongly chip dependent, and the observers should use one of the initial dark exposures to estimate the proper value for the CCD which they are using.

IV c) Observations of flux standard stars

The observation of flux standard stars at the same spectrograph setting as the program objects can be used to obtain an absolute calibration of the spectra or, in a more restricted application, to take out the blaze

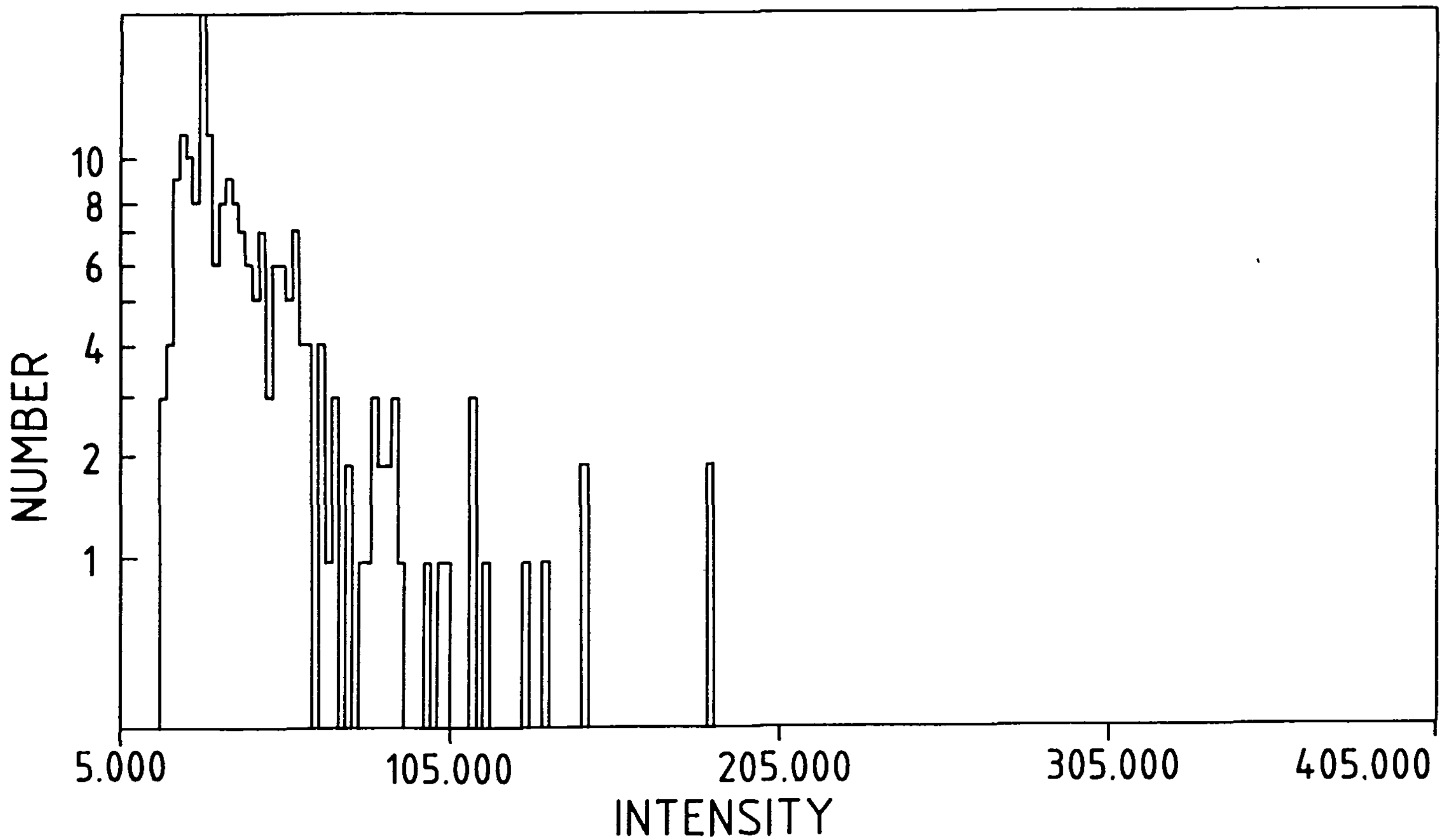

Fig. 20: Histogram of detected cosmic ray events on a 30 m dark exposure of the thinned RCA mounted on CASPEC. In the x coordinate, the AD units (1 ADU = $15e^-$) are sampled in bins of 2 units. Only events with energies larger than 200 electrons are counted.

function in each order.

The main problem which one encounters is the lack of standards with appropriate wavelength spacing. At present data are available for five stars at 12 Å resolution and they are implemented in the data reduction software (courtesy of J. Baldwin of Cerro Tololo Inter American Obs.). The stars are the following:

Star name	Approximate Position	Spectral Type	Mag.	Ref.
LTT 1020	01 52 - 27	g	11.5	1
LTT 3864	10 30 - 35	f	12.1	1
Fei 56	12 04 + 11	B5p	11.1	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.

These standards require ~ 30^m integration when observed at the resolution of CASPEC and the wavelength spacing is still somewhat wide. We have started a calibration program which includes the bright standard η HYD, θ CRt and 9 SGR to permit shorter calibration exposures. The results should be available in early 1985.

IV d) Monitoring and subtraction of the night sky spectrum

In the standard configuration of the spectrograph, the emission lines of the airglow λλ5889,5896 (NaI), λ5577, λλ6300, 6323 (OI) are well detected in exposure times of about one hour. They come in useful to check the accuracy of the wavelength calibration and to measure the instrumental line profile.

To the red of H_α, the B and A absorption bands of O_2 are quite conspicuous. The solar spectrum can also contaminate long exposures taken close to the full moon time. The intensity of the sky spectrum depends on the entrance aperture, on the position of the target with respect to the moon and on the sky conditions, like presence of haze or clouds.

Sky subtraction is made difficult by the limitation on the slit size (pgph. IVa). Only if the seeing is a fraction of slit length, is it possible to separate the spectrum of the object from that of the background and to achieve an accurate subtraction. With the 31.6 lines/mm échelle, this condition is met only at red wavelengths.

V Echelle data reduction at ESO

At the telescope, a quick evaluation of the data quality can be obtained within the IHAP data reduction system at the HP computer. The command ECHELLE extracts the spectrum by moving an adjustable slit of variable length along one order. The latter is identified with two cursor positions.

A batch programm, ϕ CCSSPP can be used on the original image to extract one order with a preliminary background subtraction.

A complete data reduction program, which includes the flat fielding of the image, the wavelength calibration and order extraction is implemented on the VAX 11/780 computer at Garching (ref. 3). To use the program, the normal procedure to reduce data at Garching have to be followed. The program runs also at the VAX on the third floor of the 3.6 m dome, but since no assistance is provided, its use is recommended only to visitors who are familiar with the VAX computer. Extraction and calibration of a spectrum may take more than one hour. Observers are advised to keep the number of formats they are using at a minimum to limit the reduction time. This is particularly necessary if they then plan to reduce their data in Garching. Changes in the central wavelength, in the slit size and in the format of the CCD should be avoided whenever it is possible.

Acknowledgements

Several people have contributed to this project since its beginning in Geneva. A short history and a list of people are given in refs. 1 and 4.

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