EUROPEAN SOUTHERN OBSERVATORY

BULLETIN NO. 11

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

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

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

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THE COUDÉ SPECTROGRAPH OF THE 1.52 m TELESCOPE

H. John Wood, Bernhard Wolf, Eric Maurice

The spectrograph was built by the REOSC Corporation in Paris. It was constructed according to an optical design by the ESO Instrumentation Committee and now equips ESO's 1.52 m telescope in Chile. It is a closed coudé spectrograph (Fig. 1), mainly cylindrical in shape to give maximum rigidity, and is composed of an entrance slit, a collimator (spherical mirror) with a focus of 6 m, three gratings of which only one can be used at a time, and three photographic cameras of which also only one can be used at a time. A fourth holographic grating will soon be added to give an intermediate dispersion between cameras II and III.

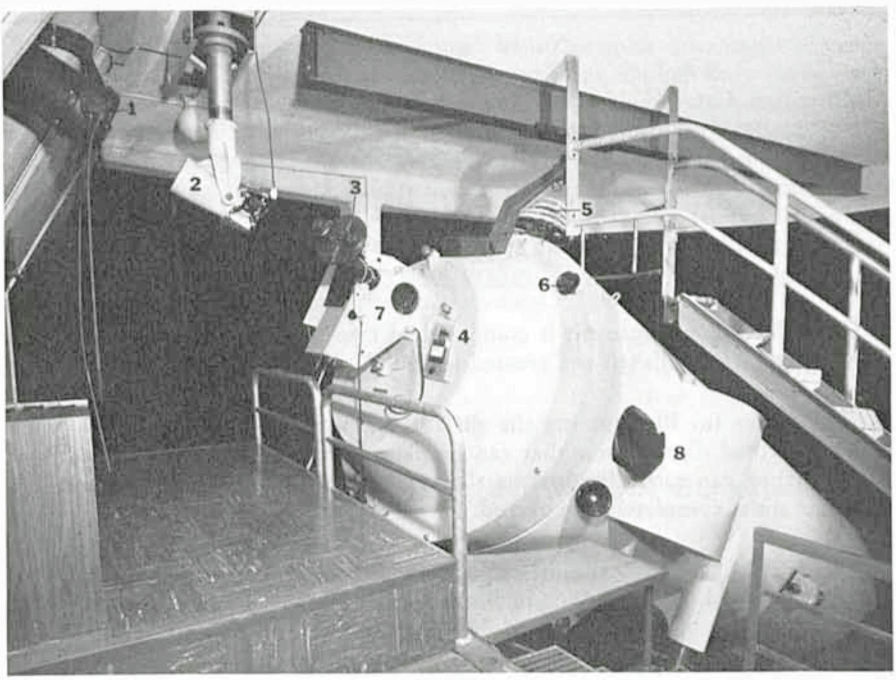

Fig. 1: The coudé spectrograph of the 152 cm telescope on La Silla. The deviating plate is at location 1 in the photograph. At 2 is the wide-field viewer which is shown in the beam. 3 is the slit-viewer and 4, the exposure meter. 5 shows the hand-wheels for changing gratings and spectral ranges. 6 is a control for changing neutral-density filters in the exposure meter. Controls for focusing and guiding the telescope are available at the coudé focus. The slit, calibration wedge, rocking plate, and comparison and photometric sources are enclosed in the slit box at 7. Camera I can be seen at 8.

The incident beam at the collimator is directed from south to north following the polar axis. The beam reflected by the collimator remains in the meridian plane but passes underneath the incident beam and goes to the grating that is being used, at a distance of 5 m from the collimator. (See Fehrenbach, ESO Bulletin No. 3, February, 1968, p. 36, Fig. 2, for the general optical layout of the spectrograph.) The grating returns it either to the east with a 51°6 deviation towards the camera with 41 cm focal length (camera I) or to the west with a 51°6 deviation towards the camera with 67 cm focal length (camera II). In either case the grating works at nearly normal diffraction. The grating can also send the diffracted light towards the west with a deviation of 10° into the camera with 2.50 m focal length (camera III). The angles of incidence in this case are:

18°2 and 20°0 for grating A 1
24°0 and 27°3 for grating A 2
18°4 and 22°6 for grating B

The characteristics of these Bausch & Lomb gratings are as follows:

Grating	B & L Cat. No.	No. of lines per mm	Blaze angle	Useful area	Support
A 1	35—53—40—263	1,200	14°14′	200 × 306	220 × 350 × 50 mm
A 2	35—53—40—34	1,200	21° 6′	200 × 306	220 × 350 × 50 mm
B	35—53—40—37	771	16°49′	200 × 306	220 × 350 × 50 mm

I. The reflecting entrance slit is composed of two jaws, each formed by a block of hardened steel polished and treated for good reflection.

II. The device for illuminating the slit for taking comparison spectra includes two pentagonal silica prisms that can be placed above and below the centre of the slit; they can each illuminate a slit height of 12 mm and can be removed until the slit is completely uncovered.

III. With a **"slit viewer"** the direct sky image reflected on the jaws of the slit can be examined. Its surface is inclined 15° to the axis of the incident beam: consequently the viewer is inclined 30° to the axis of the beam.

Optically it is composed of:

(1) a lens system specially calculated for this purpose and formed by four doublets,

(2) a large-field eyepiece giving an over-all enlargement 2.7 X and with a field of 60 mm (4 arc minutes) at the slit,

(3) a very powerful interchangeable eyepiece that gives the viewer a field of 19 mm (1.5 arc minutes) and an enlargement of 10 X.

In addition to the slit viewer, a wide-field (9 arc minutes) viewer can be swung into the beam. This viewer gives a reversed sky image.

IV. With the **"rocking plate"** the stellar spectra can be widened. A thick silica plate placed in front of the spectrograph rocks on an axis perpendicular to the slit. The rotation is such that the image of the star moves along the slit in a linear function of time. The amplitude of this motion is determined by a heart-shaped cog. An index moving along a scale permits the direct reading and setting of the displacement of the star on the slit. An additional computer-controlled rocking window not connected to the spectrograph provides a similar function (see XII Deviating plate).

V. The **collimator mirror** is of 6 m focal length and is mounted on a special holder for focusing.

VI. There is a **"grating carrying column"** which permits instantaneous changing of the gratings. It has provision for four gratings, though only three are in use at present. A large driving-wheel changes the grating. Four smaller wheels adjust the setting of the grating so as to throw light into the desired camera and to adjust the spectral regions to a value that has been determined beforehand; there are six different settings for each grating. An automatic mechanism turns the grating through 180° in its plane, when changing from a camera on the right to a camera on the left side. Both the carrying column and the holders of the gratings are locked by powerful brakes. The brakes are released at the moment of operation through pneumatic valves.

VII. Photographic cameras

1. Camera I of 41 cm focal length

This f/1 camera is diaphragmed by the grating to f/2.05, with a total field of 20 degrees.

It is formed by a catadioptric system consisting of a correcting objective composed of positive and negative components and a spherical concave mirror of 63 cm diameter. The system's diaphragm is located on the grating at about 33 cm in front of the correcting lenses. Because of astigmatism, only the central portion of the plate can be used.

2. Camera II of 67 cm focal length

This f/1.63 camera is diaphragmed by the grating to f/3.3 with a total field of 20 degrees. As with camera I, it is formed by a catadioptric system consisting of a correcting objective composed of positive and negative components and a spherical concave mirror with 77.5 cm diameter. The system's diaphragm is located on the grating about 33 cm in front of the correcting lenses. Astigmatism reduces the field considerably.

3. Camera III with 2.50 m focal length

This camera is formed by a spherical mirror with a radius of curvature of 5 m and a diameter of 1.12 m. A plane mirror reflects the image downwards to the plate.

VIII. Electric verification circuits show a light on a panel when the entrance slit of the spectrograph is opened, provided all the previous operations (introduction and opening of the plate-holder, orientation of the grating, etc.) have been carried out correctly. The light also indicates the spectral region which has already been set. The circuit contains a number of microswitches placed at all crucial points.

IX. With the **"exposure meter"**, one can integrate a certain amount of the light that enters into the spectrograph. The exposure time may then be adjusted according to the atmospheric conditions and according to the precision of the focusing and guiding of the stellar image on the slit of the spectrograph.

In order not to waste any light, the part of the beam that would be intercepted on the back of the plate-holders inside the cameras is used for the exposure meter by placing a narrow mirror in front of the collimator. This portion of the beam is then thrown into a Lallemand photomultiplier. The anode current of the PM charges a condenser (10^{-9} Farad).

The condenser integrates the current. Once the tension between the condenser plates is equal to 10 volts, a comparator detects it and for 0.1 sec. connects the condenser to a source of + 108 V--over a resistance of 10^{8} Ohms. Through an annex circuit, each discharge adds 1 unit to an electromechanical counter.

The exposure meter is equipped with a disk carrying optical density filters and with an automatic security system that prevents the accidental overloading of the cell.

X. The photometric calibrator for the plates in the spectrograph itself and the comparison spectrum source is located on the west side of the slit box.

Both the wave-length calibration of the spectrograms and the relative spectrophotometric calibration of the emulsion can be made in the spectrograph.

During past calibrations, a movable silica plate was placed just in front of the slit. This plate had a central transparent zone for the stellar object and on either side five zones of calibrated optical density (which makes 10 zones in all).

Previously, two six-step wedges had been in use. In Tables 3—5 (pp. 16—18), the transmission characteristics for the two old six-step wedges and for the new ten-step wedge are given. Tables 3 and 4 give the transmission characteristics of the old wedges. Data for the present wedge are given in Table 5.

The calibration source is the exit window of a small photometric sphere. A fluorine quartz objective produces, through the prisms and the slit, an image of this window.

The photometric sphere is equipped with five small entrance windows, three lamps, and one iron arc distributed along the sphere, each one illuminating one of the windows. They can all be lit at one time, or in combination, to provide a mixed calibration source.

The sources are the following: an iron arc, a neon spectral lamp, a mercury lamp, and an incandescent iodine lamp of very high colour temperature. Other spectral lamps can be inserted at the photometric sphere, if necessary. In each lamp a condenser formed by two identical spherical lenses projects the image of the sources on the corresponding window. In the parallel beam between the lenses, an interchangeable diaphragm permits adjustment of the intensities of the different sources. The spectrophotometric calibration is obtained with a density plate and not through the action of the diaphragms.

The iron-arc housing has a movable silica screen that protects the projection optics from any oxide coming from the iron-arc. This screen must be regularly cleaned in normal use.

The incandescent-lamp housing contains, furthermore, a simple device to adjust the colour temperature of the lamp in use in comparison with the first iodine lamp used with the instrument. This "secondary calibration" is only rarely used. A fifth calibration source has recently been added. It is a very high-intensity hollow-cathode iron lamp. A polarizing quartz coudé calibration is under construction and may be ready for use in mid-1975.

Two very thin deckers that can be moved separately are placed immediately in front of the slit; they permit adjustment of the height of the slit and can be used to make multiple stellar exposures on one plate.

XI. Field rotator and deviator

The field rotator diminishes the stellar light by about 30 %. It permits either elimination of the rotation around the earth's axis of the stellar field on the slit, or the rotation of the field, so that the stellar spectrum due to atmospheric refraction is always oriented along the slit of the spectrograph.

In both cases the field rotation is obtained by the rotation of an Abbé silica prism. This prism is made in such a way that, when introduced into the light beam, it will not significantly modify the focusing on the slit of the focal plane of the telescope.

To eliminate the diurnal field rotation, the prism is turned around the optical axis once in 48 sidereal hours.

To maintain the refracted image fixed on the slit, three transmitting and receiving motors (Selsyns) have to be used one after the other, acting on a receiving motor that is steering the rotation of the prism. The first motor is steered by a pendulum movable around an axis parallel to the optical axis of the telescope; it is located inside the telescope tube. The second is connected to the motion in declination of the telescope, and the third to the motion in right ascension.

By pushing a button it is possible to change instantly from a fixed stellar field position to a fixed position of the stellar atmospheric spectrum, along the slit.

With a notched knob, the initial orientation of the stellar field or the stellar spectrum can be adjusted.

The whole instrument is removable and can rapidly be put in its proper place in front of the spectrograph.

XII. Deviating plate

At the coudé exit of the polar axis, the telescope is closed by a silica plate. This plate is also used for minor guiding motions of the focal image of the telescope. To this end the plate is placed in a cardanic mounting and two stepping motors permit the inclination of the plate around two perpendicular axes. This device is very helpful for bringing back to the slit the image of a star during the exposure. (The axes are parallel and perpendicular to the slit.) This plate is now used for the oscillating widening motion, thus eliminating the need for the rocking-plate described above in section IV.

XIII. Numerical data

a) Images of the slit on the spectrogram

The size of the slit's image is given in Table 1 (p. 15).

Normally, the following slits are used:

a 300 μ slit corresponding to 20.6 μ on the plate for Camera I,

a 200 μ slit corresponding to 22.5 μ on the plate for Camera II,

a 50 μ slit corresponding to 20.6 μ on the plate for Camera III.

Fig. 2 gives the same result graphically.

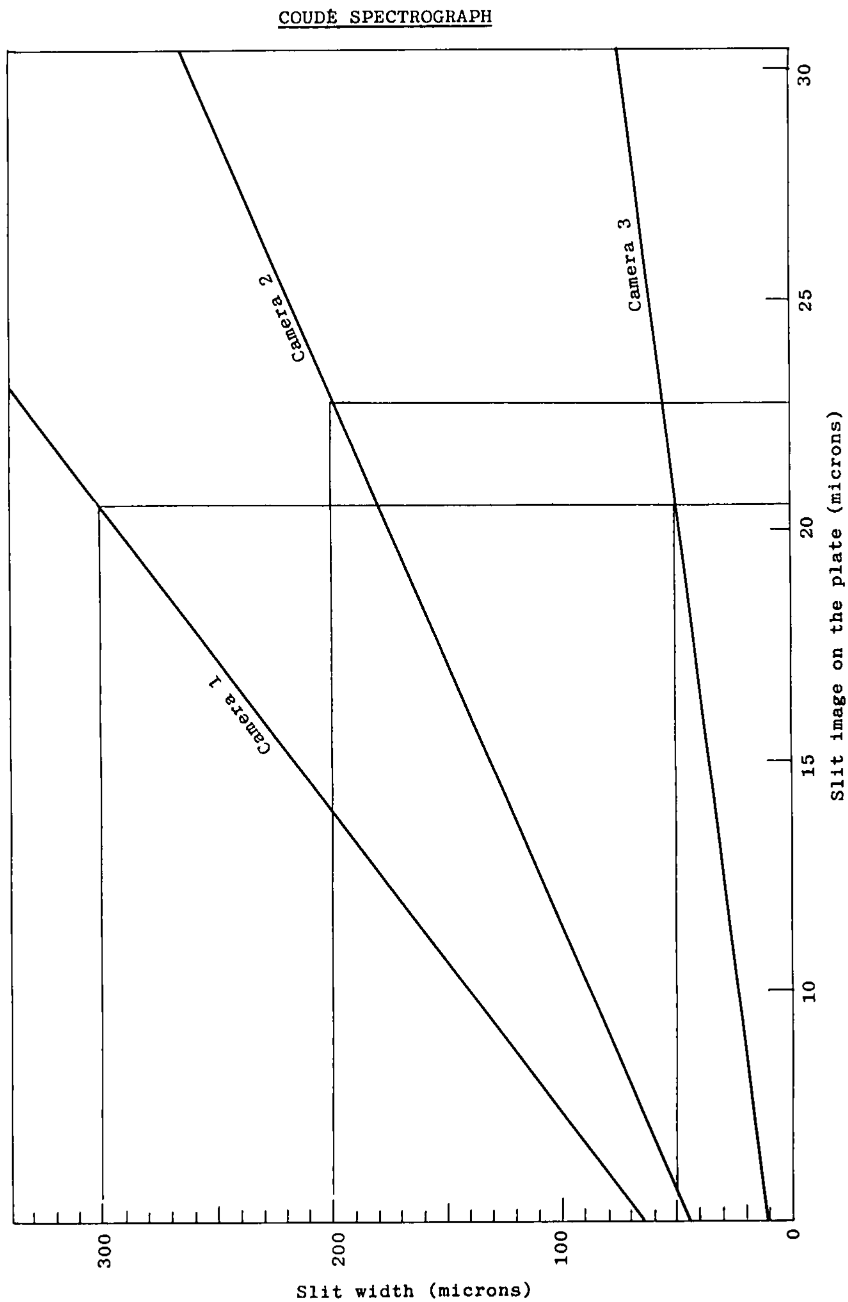

Fig. 2: The projected slit size as a function of the actual slit opening for the three coudé cameras.

b) Slit height and spectral widening

The height of the slit is set by the two prisms. A scale on a screw permits the direct reading and setting of the displacement of the two prisms. For spectra with small widening (chiefly Camera III) it is better to widen between 2 deckers to prevent vignetting by the prism housings.

Table 2 (p. 15) gives the screw reading for the prisms (column (1)) together with the corresponding height of the stellar spectrum for each camera (columns (2), (3) and 4)).

Refer to Fig. 3 for exact distances between the comparison spectra.

Column (5) of Table 2 gives the value to be set on the index for adjusting the amplitude of the rocking plate.

c) Photometric calibration

There are 10 zones, plus a central one for which there is a choice between a transmission of 1 (central prism in place) or 0 (prism removed)

Camera	Size of a zone on the plate	Distance between the two series of zones	Total height
I	0.35 mm	0.67 mm	4.30 mm
II	0.60 mm	1.10 mm	7.10 mm
III	2.25 mm	4.10 mm	26.50 mm

Wedge used:	— from the beginning (June 1969) to March 26, 1970	No. 2
	— from March 27, 1970 to January 14, 1971	No. 1
	— from January 15, 1971 to February 18, 1971	No. 2
	— from February 19, 1971 to April 9, 1972	No. 1

Since April 10, 1972 the new photometric wedge with ten steps is in use. The calibration is given in Table 5 (p. 18).

d) Exposure times

	Camera I	Camera II	Camera III
Approx. exposure times (min) for B = 5.0 mag stars taken in the zenith on IIa-O plates (Developer: MWP2) and widened to 230 μ for a seeing of 1″5 and 20 μ slit image on plate	1.5	5	210

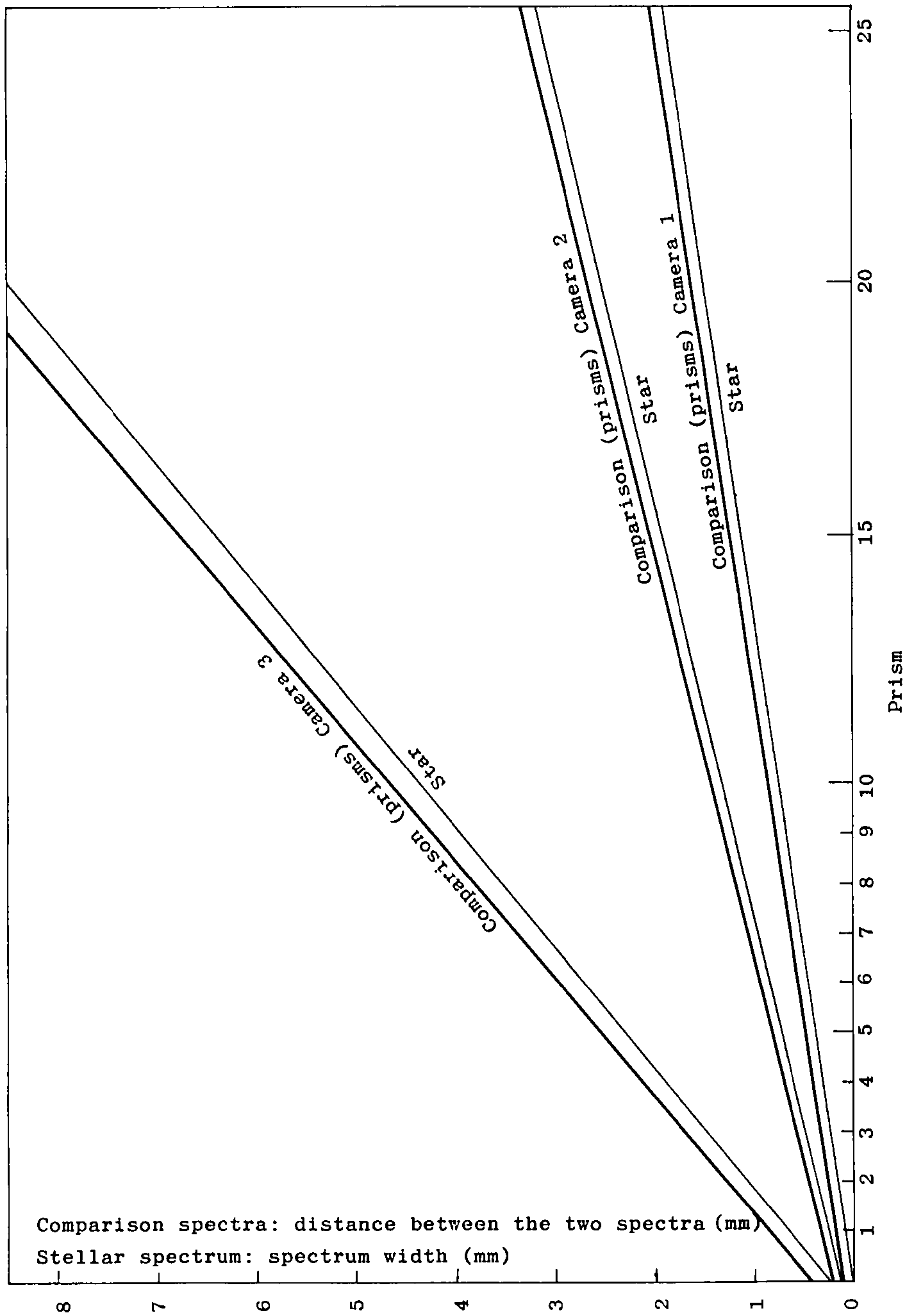

Fig. 3: Spectral widening as a function of the comparison prism setting.

e) Comparison of the gratings

Tests have proved that:

— Gratings A 2 and B are equally efficient.

The fact that grating B gives a smaller dispersion puts it ahead by a factor of 1.6 (0.55 magnitude).

— Grating A 1 is about 1.4 times more efficient than gratings A 2 and B (the gain is about 0.4 magnitude).

f) Dimensions of the plates

The plate-holders are for plates of the following sizes:

Camera I 168 (± 2) × 17.25 (± 0.25) mm

Camera II 254 (± 2) × 17.25 (± 0.25) mm

Camera III 498 (± 2) × 62.5 (± 0.5) mm

The plates that are used come in the following sizes:

168 × 254 mm, thickness = 0.035 inches for Camera I or II

8 × 10 inches, thickness = 0.040 inches for Camera II only

498 × 62.5 mm, thickness = 0.045 inches for Camera III

g) Curvature of the plate-holders.

When some plate-holders were measured it was found that:

for Camera III : R = 2.50 m

for Camera II : R = 0.92 m

for Camera I : R = 0.56 m

h) Spectral regions

Table 6 (p. 19) gives the spectral ranges available with the coudé spectrograph.

Reference

1968, Fehrenbach, Ch. "Le télescope spectrographique de 1,52 m de diamètre et son équipement", ESO Bulletin No. 3, Hamburg.

Table 1: Width of the slit's image (in parentheses, the image of slit on the sky in seconds of arc)

Width of slit's image (microns)		5	10	15	20	25	30
Corresponding width of the slit (microns and seconds of arc)	Camera I	73 (0.33″)	146 (0.66″)	219 (1.0″)	293 (1.3″)	364 (1.6″)	439 (2.0″)
	Camera II	44.8 (0.2″)	89 (0.4″)	134 (0.6″)	179 (0.8″)	224 (1.0″)	269 (1.2″)
	Camera III	12 (0.05″)	24 (0.11″)	36 (0.16″)	48 (0.22″)	60 0.27″)	72 (0.33″)

1″ = 220 μ; 1 μ = 0.00455″; 1 mm = 4.55″.

Table 2: Width of the spectrum

Prism	Camera I microns	Camera II microns	Camera III microns	Rocking mm
0	40	70	250	(adjusted according
1	100	160	640	to conditions)
2	160	260	1.00 mm	9.5
3	220	370	1.38 mm	14
4	280	470	1.75 mm	19.5
5	350	570	2.12 mm	24
6	410	680	2.50 mm	29
7	470	780	2.86 mm	34
8	530	880	3.24 mm	39
8.6* maxi	570	940	3.46 mm	42

* Limit imposed by the rocking plate.

Table 3: Absolute transmission Table (%)
Wedge No. 1

λ	T_1	T_2	T_3	T_4	T_5	T_6	T_{glass}
3,200	1.35	1.94	4.62	10.87	23.59	43.67	83.45
400	1.48	2.13	5.31	13.22	25.86	46.80	89.41
600	1.57	2.31	5.62	12.06	25.86	47.34	90.45
800	1.62	2.39	5.92	12.06	25.57	47.45	90.66
4,000	1.68	2.50	6.11	12.06	25.39	47.45	91.50
200	1.74	2.61	6.30	12.00	25.10	47.34	91.92
400	1.80	2.69	6.44	11.95	24.98	47.12	92.34
600	1.89	2.80	6.65	11.98	24.70	47.01	91.71
800	1.97	2.90	6.84	11.95	24.59	46.91	91.71
5,000	2.07	3.03	7.05	12.06	24.59	47.12	92.56
200	2.19	3.17	7.30	12.12	24.59	47.12	92.34
400	2.31	3.31	7.52	12.23	24.64	47.12	92.34
600	2.44	3.44	7.67	12.34	24.70	47.34	92.34
800	2.59	3.61	8.02	12.48	24.93	47.56	90.66
6,000	2.69	3.79	8.19	12.57	24.76	47.34	91.50
200	2.83	3.92	8.36	12.63	24.87	47.34	91.50
400	2.96	4.06	8.61	12.77	25.27	47.89	91.50
600	3.17	4.25	8.95	13.07	25.86	48.44	91.92
800	3.32	4.45	9.23	13.38	25.86	49.00	93.63
7,000	3.44	4.50	8.61	13.22	25.86	47.89	87.38
200	3.65	4.77	9.44	13.69	26.47	49.00	91.50
400	3.73	4.77	9.89	13.38	25.86	47.89	89.41
600	4.00	4.99	9.44	13.69	26.47	50.14	91.50

Table 4: Absolute transmission table (%)
Wedge No. 2

λ		T_1	T_2	T_3	T_4	T_5	T_6	T_{glass}
3,200	A	1.55	2.01	4.89	11.43	25.28	43.96	85.30
400		1.59	2.26	5.30	11.97	25.86	47.10	89.32
600		1.66	2.46	5.56	11.86	25.93	47.75	90.56
800		1.68	2.55	5.76	12.08	26.04	47.42	90.56
4,000		1.71	2.68	5.93	12.08	25.45	47.53	91.19
200		1.75	2.75	6.10	12.00	25.10	47.32	90.98
400		1.78	2.84	6.26	11.94	24.87	47.10	90.77
600		1.84	2.95	6.46	11.94	24.70	46.67	90.98
800		1.92	3.08	6.70	12.03	24.64	46.99	91.19
5,000		2.00	3.21	6.92	12.05	24.59	46.99	91.61
200		2.10	3.35	7.15	12.14	24.64	46.99	91.40
400		2.20	3.50	7.40	12.26	24.70	47.16	91.51
600		2.32	3.64	7.62	12.36	24.81	47.10	91.40
800		2.46	3.80	7.89	12.59	25.04	47.32	91.82
6,000		2.56	3.95	8.06	12.62	25.04	47.32	91.40
200		2.77	4.21	8.60	13.25	25.86	49.32	94.18
400		2.85	4.23	8.54	13.13	25.39	48.42	91.82
600		2.96	4.45	8.88	11.94	25.93	48.08	91.19
800		3.07	4.52	8.92	13.16	25.93	49.66	91.61
7,000		3.25	4.67	8.40	13.59	25.57	46.56	92.46
200		3.41	4.83	9.32	13.43	25.86	48.20	91.40
400		3.49	4.83	9.53	13.43	27.08	49.32	91.40
600		3.49	4.94	9.76	13.74	27.71	49.32	91.40

Table 5: Absolute transmission table (%) 10-step wedge

λ	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{glass}
3140	2.7	5.5	9.1	11.9	20.4	26.4	34.6	44.8	53.7	85.1	91.9
3540	2.9	5.5	8.6	11.7	20.7	25.1	33.9	44.4	55.1	87.4	92.1
3940	3.2	5.6	8.1	11.6	20.7	24.1	33.1	44.4	56.5	88.9	92.7
4340	3.6	5.7	7.9	11.7	20.7	23.5	32.6	44.4	57.9	89.6	92.6
4740	3.9	5.8	7.8	11.9	20.8	23.4	32.6	44.4	58.9	90.5	92.5
5140	4.3	5.9	7.8	12.2	20.7	23.1	32.4	44.9	60.4	90.8	92.6
5540	4.6	6.2	7.8	12.4	20.6	23.0	32.8	45.4	61.8	90.8	93.2
5940	4.9	6.4	7.8	12.7	20.1	23.2	33.1	46.4	62.8	91.3	93.8
6340	5.2	6.7	7.9	13.1	19.8	23.2	33.4	46.9	63.8	91.6	92.4
6740	5.4	6.9	8.0	13.4	19.6	23.3	33.9	47.5	64.7	91.5	92.9
7140	5.6	7.2	8.2	13.8	19.5	23.5	34.4	48.0	66.0	91.8	92.7
7540	5.9	7.4	8.3	14.1	19.6	23.6	34.7	48.7	66.9	92.0	93.2

Table 6: Spectral ranges of the coudé spectrograph

Range No.	Grating	Camera	Dispersion Å/mm	Plate Centre λ	Plate edges λ — λ
1		I	20.0	4150	2700 — 5550
2		I	20.0	4750	3250 — 6250
3	A 1	II	12.3	3790	2200 — 5450
4		II	12.3	4925	3500 — 6350
5		III	3.3	3450	2700 — 4200
6		III	3.3	4280	3500 — 5000
7		I	20.2	5300	3960 — 6850
8		I	20.2	5700	4360 — 7250
9	A 2	II	12.4	5300	3760 — 6800
10		II	12.4	6040	4450 — 7600
11		III	3.3	5400	4700 — 6100
12		III	3.3	6300	5500 — 7000
13		I	31.3	6250	3650 — 8850
14		I	31.3	7500	4900 — 10100
15	B	II	19.4	6375	4150 — 8600
16		II	19.4	7450	5050 — 9850
17		III	5.05	5800	4800 — 7000
18		III	5.05	7800	6800 — 9000

Note: The ranges used with grating B require minus-blue filters to eliminate overlapping orders. These filters are available at La Silla.

The spectral range is given for the whole length of the plate and is provisory. The region without astigmatism (especially cameras 1 and 2) is approximately half of the total length of the plate.

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THE ESO SPOT SENSITOMETER

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I. Introduction

This paper provides a description and operation manual for the ESO spot sensitometer. The design contains many aspects of the sensitometers described by D. W. Latham (1969) and Wu, Anderson, Rosendahl, Marty and Bucholtz (1972). We are especially indebted to Dr. Rosendahl for communicating details of his design in advance of publication.

Fig. 1 shows the sensitometer set up in a laboratory on La Silla ready for photoelectric calibration. Starting from left to right on the table, we have in the photograph a wooden box housing five two-inch square neutral density filters, line voltage regulator, pulse-counting timer and counter, the sensitometer lamp housing, integrating sphere, tube stack, phototube housing and amplifier discriminator, and finally, at the extreme right, the high-voltage power supply.

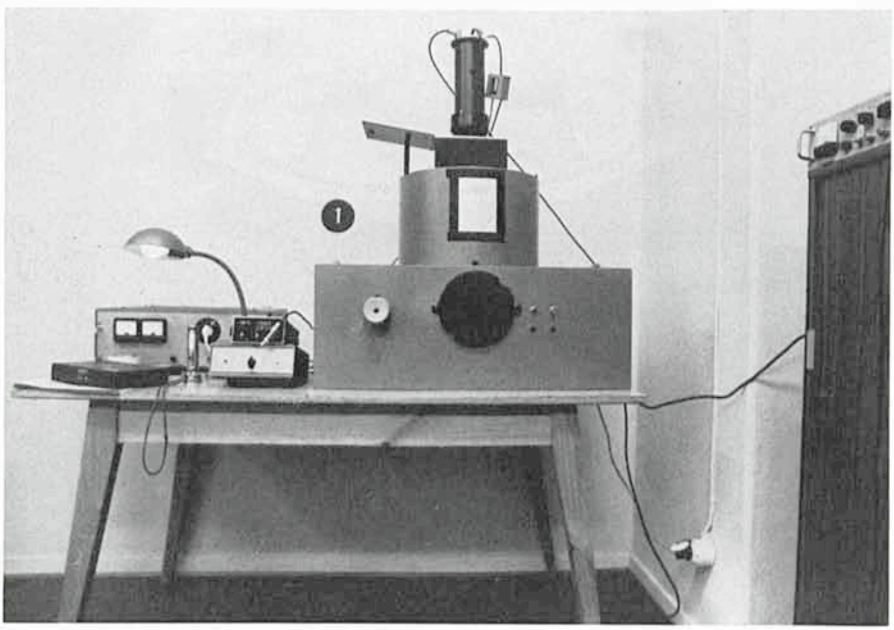

Fig. 1: The ESO spot sensitometer with photoelectric calibrator on La Silla.

The sensitometer utilizes a variable light source and filter/diaphragm combination, so that a range of a factor 400 in exposure can be obtained in order to match exposure times of astronomical photographs. The photoelectric calibrator system is used not only to calibrate the intensities of the 21 spots but also to regulate the light level to assure equal exposure times. In fact, the sensitivity of the photoelectric calibrator system is the absolute standard for the tube sensitometer, not the output of the lamp.

Let us follow the light through the system giving a description of the various design features. The lamp is either a tungsten bulb or a mercury tungsten lamp and is placed in the lower part of the main lamp housing. Access to the lamp and filter holder is through the round black cap in the front of the sensitometer box.

Fig. 2 shows the sliding filter/diaphragm holder situated inside the opening to the lamp housing. A thumb-screw directly above the opening releases the frame

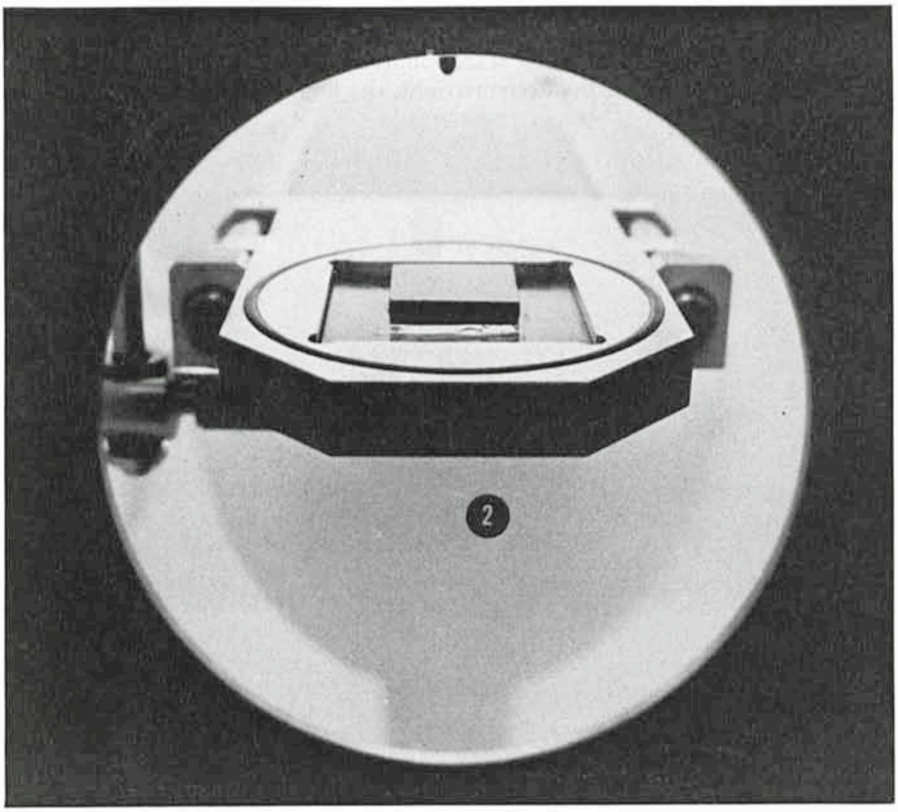

Fig. 2: The filter/diaphragm frame in loading position.

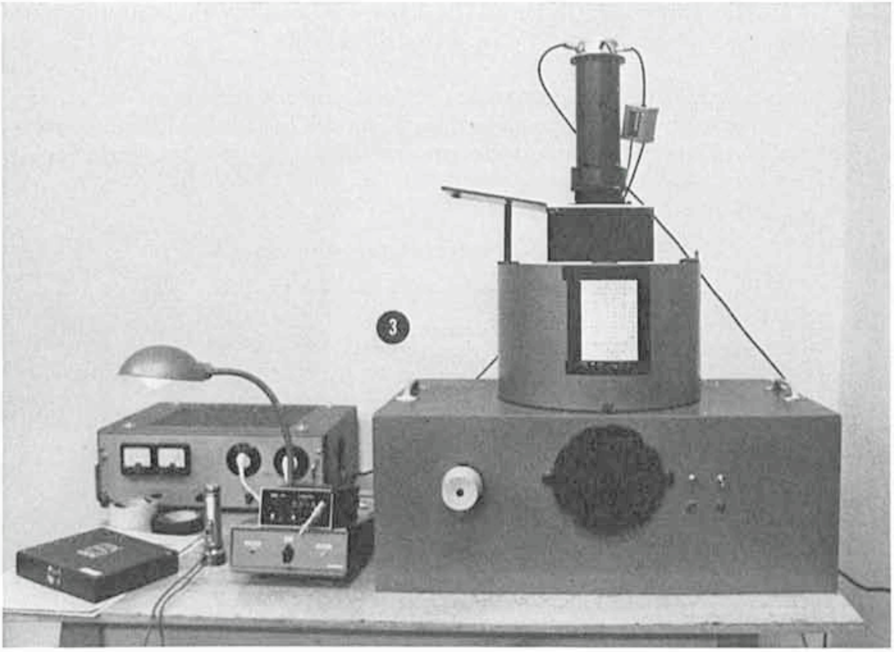

Fig. 3: Another view showing the instrumental set-up.

and the filter housing can be slid out through the opening so that various filters and diaphragms can be placed there. In normal use, it has been found that a Kodak diffuser glass two by two inch square used at this point in addition to the main diffuser which is 15 cm square within the integrating sphere gives the most uniform distribution of light at the level of the entrance to the tube stack. A cooling fan system within the lamp housing should be used whenever the lamp is turned on. A maze at both the entrance and exit air-holes left and right on the lamp housing box ensures that no light escapes from the lamp housing box during a photoelectric calibration or photographic exposure. The light entering the integrating sphere is transmitted directly to the diffuser plate and also reflects from the white walls of the interior of the sphere. The "vignetting" of the plate depends on the height of the plate above the filter-diaphragm aperture. That is, one can change the ratio of light directly transmitted to the diffuser plate and the light reflected from the walls and especially the top inner surface of the integrating sphere. It was found by photoelectric measurement that a light distribution uniform to within 2 % could be obtained when the diffuser was 40 turns down from the topmost position (approximately one quarter of the distance).

In Fig. 3, one can see on the right-hand side of the integrating sphere a small knob which rotates four screws simultaneously to raise and lower the diffuser plate within the integrating sphere. The light continues to the entrance plate of the tube stack in which are 21 precisely drilled holes.

Table 1 gives a list of the approximate hole diameters and measured relative intensities from a photoelectric calibration, using ESO filter No. 98. Each sensitometer tube stack contains ten diaphragms for eliminating scattered light within the tube.

Table 1: ESO sensitometer spot sizes

Spot No.	Diameter (mm)	Measured relative intensity
1	0.41	0.093
2	0.46	0.112
3	0.51	0.158
4	0.57	0.182
5	0.66	0.257
6	0.74	0.312
7	0.84	0.373
8	0.94	0.440
9	1.07	0.620
10	1.19	0.716
11	1.40	1.00
12	1.59	1.23
13	1.78	1.41
14	1.99	1.58
15	2.26	2.28
16	2.58	3.02
17	2.95	4.02
18	3.26	4.94
19	3.66	6.07
20	4.22	7.23
21	4.80	8.60

Fig. 4 shows the exit hole pattern for the tube stack, small guide holes to the left and right of each 4 mm exit hole enable one to accurately centre the photoelectric calibrator over each hole. The cross-pattern at the bottom of the picture provides a guide for positioning the photoelectric photometer over each hole. Also visible in the photograph are eight small screw-holes for positioning a four-by-five inch plate for sensitometric purposes.

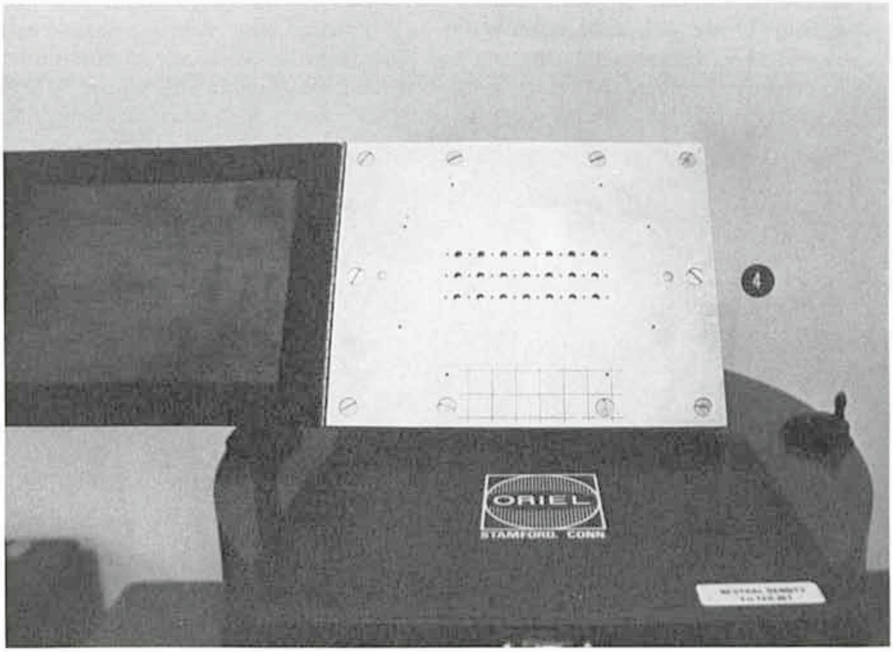

Fig. 4: The exit hole pattern of the tube stack. The grid on the lower part of the plate is for guiding the PM head during photoelectric calibrations.

While it is anticipated that four-by-five inch plates would normally be cut for emulsion calibrations, it has been found that the end of a coudé camera III plate can also conveniently take the 21 spots.

II. Photoelectric calibration

Fig. 5 shows the photoelectric photometer in its storage box. In the upper right is a block similar to the tube stack but containing only one hole. It is used for calibration of the intensity distribution across the exit aperture of the integrating sphere. In the upper left, diaphragms and filters can be seen. In the lower right is a copper tube with diffusing screen for focusing of the image of the tube stack exit hole on the photo-cathode of the photo-multiplier tube. Finally, a photomultiplier tube housing, including field lens and dark slide, is shown in the foreground of the box.

The photomultiplier tube housing is a model PR-2100 from Products for Research. The photomultiplier is an EMI 9558 B with S-20 response. The pulse-counting data system was constructed by Astrometrics and includes an amplifier discriminator seen near the top of the tube housing in Figs. 1 and 3. The calibration procedure is as follows: the system is set up as shown in Fig. 1 with all power supplies connected to the line through a suitable line voltage regula-

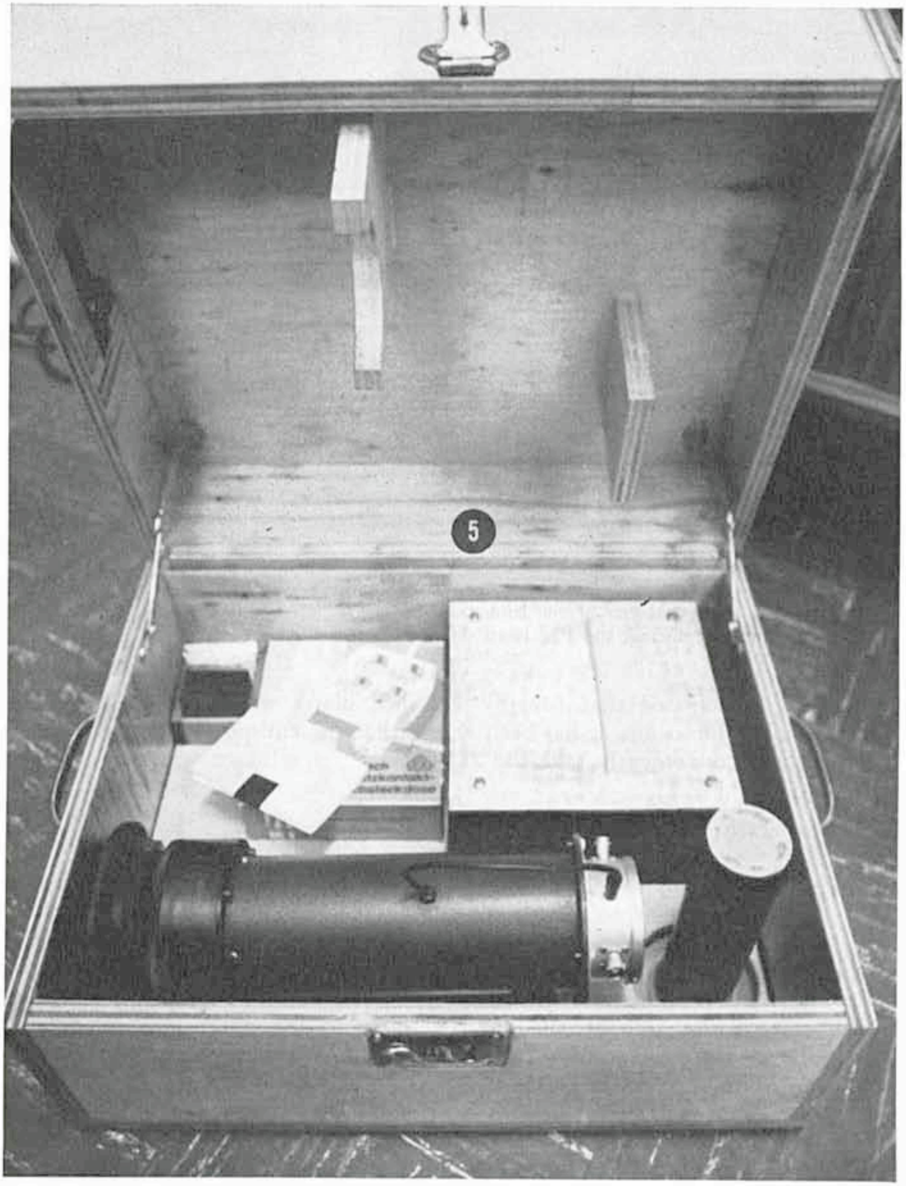

Fig. 5: The PM head and other components in storage box.

tor. The high voltage power supply is connected to the cathode connector of the photomultiplier tube housing. The anode is connected to the amplifier discriminator of the pulse-counting unit and the entire photomultiplier housing is put on top of the tube stack in position of the central hole in the middle row, hole No. 11. Hole 11 serves as a standard for measuring the relative brightness of the other holes.

The calibration is divided into three parts, that is, the lamp is reset to a different intensity three different times. The first time we set the lamp at about 37 % of full brightness which gives an intensity of 90 kHz on spot 11. That is, if the dark current were 4 kHz, for example, then the total reading on the lamp on spot 11 would be 94 and the brightness of the lamp minus dark would be 90. Then we proceed to measure spots No. 21, 20 and 19 followed by another measurement of the brightness of spot 11. Typical values and the proper measuring sequence for these intensities are shown in Table 2. The calibration is continued in this form with sequences of no more than four or three holes measured between measurements of the brightness of hole 11 and dark current measurements.

Once one has finished the calibration of the first row holes 21 through 15, change the lamp to approximately 77 % brightness or an intensity with dark current subtracted of approximately 490 kHz. This is to make the total measuring range of intensities for the second row approximately equal to those of the first row, so as to minimize differential coincidence corrections in the pulse-counting system.

Table 2: Calibration of February 20, 1973

Spot No.	Reading	Reading-dark	I/I_{11}
(Diaphragm 23 mm, Filter ESO No. 98 "B") (Lamp 37 %)			
Dark	3.3	—	—
11	94	90	—
21	778	774	8.60
20	655	651	7.23
19	550	546	6.07
18	449	445	4.94
17	366	362	4.02
16	276	272	3.02
15	209	205	2.28
11	94	90	—

Table 2 (continued)

Spot No.	Reading	Reading-dark	I/I_{11}
(Diaphragm 23 mm, Filter ESO No. 98 "B")			
(Lamp 77 %)			
11	494	490	—
14	777	773	1.58
13	696	692	1.41
12	605	601	1.23
11	493	489	1.00
10	354	350	0.716
9	307	303	0.620
8	219	215	0.440
11	493	489	—
(Lamp 100 %)			
Dark	3.6	—	—
11	575	571	—
7	217	213	0.373
6	182	178	0.312
5	151	147	0.257
4	108	104	0.182
3	94	90	0.158
2	68	64	0.112
1	57	53	0.093
11	574	570	—
Dark	3.6	—	—
(Use dark 4 for all readings)			

Finally for the last row, the lamp is turned to 100 % which yields approximately 570 kHz for hole 11 and holes 7, 6, 5 and 4, 3, 2, 1 are measured.

The total intensity range of the 21 spots is approximately a factor of 100. That is, if hole 11 is unity, then hole 21 is normally about 8.6, while hole No. 1 is normally 0.09. Calibrations during the first six months of operation of the sensitometer have been carried out using a 23 mm diaphragm, a two-by-two inch diffusing plate, and ESO No. 98 "B" filter (see Fig. 2).

III. Photographic use

It is recommended that a photoelectric calibration be carried out every time the sensitometer is used for a series of photographic calibrations. In other words, it is wise to calibrate it for each wavelength range and for each observing run in which it is used. It is important, of course, to clean both the entrance holes and the exit holes with air from a rubber bulb. If a first test plate shows too many shadows of dust particles, it is wise to reclean with a camel's-hair brush the glass plate which lies directly underneath the exit holes. However, if disassembly of the tube stack is required it is preferable that this be carried out by the staff astronomer responsible for the instrument.

Normal exposures for II a-O plates are two minutes with the lamp on 100 % intensity which reads about 570 kHz with dark current subtracted on hole 11.

Films and plates for the Chilicass, coudé, GPO and Schmidt were tested using the configuration described above and all exposures were satisfactory at about two minutes. Table 3 lists the factors of attenuation with the system using various diaphragms. Thus it is possible to obtain, through the use of diaphragms, neutral density filters and the variable light source whatever exposure time is required for the plate.

Table 3: Diaphragm factors

Diameter (mm)	Area (mm^2)	I/I_{23}
10	78.54	0.189
16	201.06	0.484
23	415.47	1.00
33	855.30	2.06
42	1385.44	3.33

IV. Conclusion

The set-up, photoelectric calibration, and use of the ESO spot sensitometer has been described above. The intensity distribution across the spots has been found to be quite uniform and the images of dust particles resting on the glass plate under the exit holes are sharp. One can avoid these when measuring the densities in the individual spots. A typical calibration curve is shown in Fig. 6. The plate, shown in Fig. 7, was from a 36 plate box opened May, 1972 with emulsion number 2 AO R1G1/5151 and is labelled "T5".

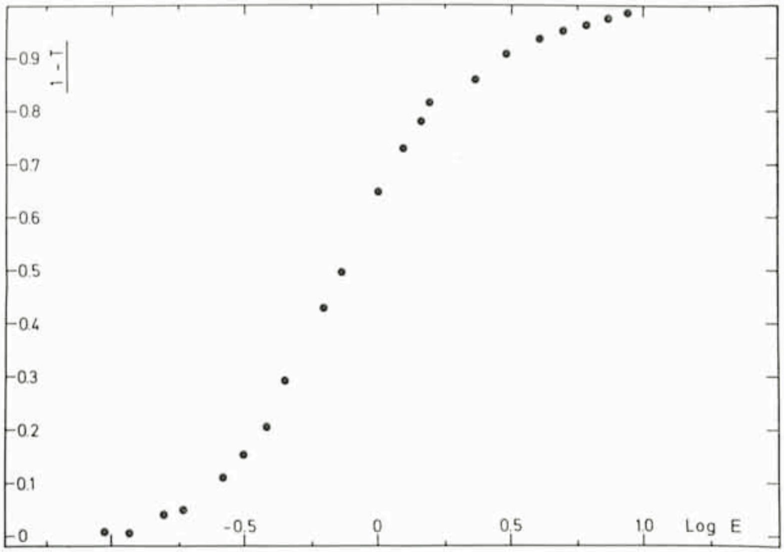

Fig. 6: The characteristic curve of II a-O emulsion 2 AO R1G1/5151 from coudé camera III plate "T 5" developed 15 m in D-76. Details of the exposure are given in the text.

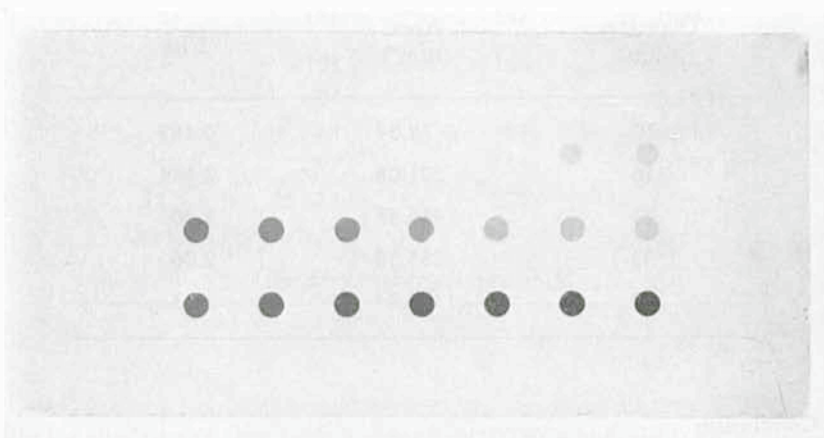

Fig. 7: Coudé test plate T 5 showing the distribution of the spots.

Care should be taken to store the instrument in a secure location and it is intended that the photoelectric photometer system be used only for calibration of this device. The sensitivity of II a-O and other Kodak plates will be calibrated in terms of the sensitivity of the photocathode of the particular EMI 9558 B photomultiplier tube presently contained in the photomultiplier housing. The tube has serial No. 22261.

Acknowledgements

The instrument was built by Serge Balon. Sr. Rolando Vega has carried out a number of the calibrations and measured the plates with the Santiago Grant machine.

References

D. W. Latham (1969): *AAS Photo Bull.* No. 1, page 3.

Wu, Anderson, Rosendahl, Marty and Bucholtz (1972): *AAS Photo Bull.* No. 1, page 9.

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THE CASSEGRAIN SPECTROGRAPH RV CASS

Eric Maurice

This article gives the necessary data for obtaining a "theoretical" knowledge of the Cassegrain spectrograph RV Cass and for preparing an observing programme.

There is a complete instruction manual on the spectrograph which the visiting astronomer may obtain from the ESO Headquarters in Hamburg or from Geneva, or upon his arrival in Chile. The complete instruction book is composed as follows:

I. Description and data

II. Instruction manual

III. Adjustment and maintenance (this is intended only for the staff in Chile)

IV. Reduction of the plates.

A French version of this text is also available at ESO.

GENERAL DESCRIPTION AND PRINCIPLE OF THE SPECTROGRAPH

Principle and some data

This spectrograph was built according to the principle of the white pupil (A. Baranne, 1955).

A description of the spectrograph and a draft of the principle may be found in ESO Bulletin No. 7.

Summary of some essential data:

— *slit:* it is aluminized on the field lens. The lens gives an image of the large mirror of the telescope on the grating. The image is reformed by the field mirror on the correcting doublet of the catadioptric camera.

— focal length of the *collimator* (Littrow mounting) .... 769 mm

— equivalent focal length of the *camera* .... 96 mm

— actual opening of the camera f/2

— magnification slit / image, approx. 7.5

The spectrograph itself is a closed triangular structure. It is connected to the telescope by a "tripod" that contains all the necessary accessories of the slit surroundings.

Additional information on observing results is found in "Spectrographic and Photometric Observations of Supergiants and Foreground Stars in the Direction of the Large Magellanic Cloud" (A. Ardeberg, J. P. Brunet, E. Maurice, L. Prévot 1972, Astron. & Astrophys. Suppl. Ser. 6, 249) in the chapter on Spectrographic Observations, Radial Velocities and Spectral Classification.

For the proper use of the spectrograph all information will be given at La Silla.

Description of the spectrum widening device

The widening is obtained by rocking a plane parallel plate in front of the slit. The rocking amplitude can be changed instantaneously. The rocking period is 15 s., which is very convenient for short exposures.

There are two rocking plates with thicknesses of 10 and 20 mm, respectively.

The thin plate permits a spectral widening between 180 and 400 microns. (Higher widening is possible but not recommended because the plate then has to be inclined considerably to the light beam and absorbs much light; furthermore, the quality of the widening is not as good.)

The thick plate permits widening from 350 μ to about 1.2 mm.

If possible, a programme should be planned so as to obviate frequent changing of the rocking plate. Observers who have only a small number of stars to take at a large widening, are advised to do the widening with the fine movement of the telescope.

Photometric calibration device

The source consists of a fluorescent powder excited by a quartz mercury tube. The image of this source is formed in the plane of a rotating disk and then transmitted to the grating. The rotating disk contains three open sectors, forming 13 zones on the slit. The illumination of the zones is given in Table 1.

The rotating sector makes 50 rotations per second, thus producing 150 illuminations per second on the film. The exposure time can be varied in two ways:

— by changing the voltage on the mercury tube,

— by changing the effective height of the tube by means of a diaphragm.

In this way, exposure times ranging from a few minutes to about 40 minutes can be obtained.

This device is contained in a cylindrical box which is substituted for the widening device. It is also necessary to place in front of the slit a lens to correct the aperture of the beam entering the spectrograph.

There are 13 zones with a width on the film of about 0.5 mm. The width of the complete calibration is 6.4 mm.

Table 1 gives the value of $\frac{I_i}{I_0}$ corresponding to each "i" zone.

The comparison spectrum is the emission spectrum of the mercury.

Table 1: Values corresponding to the zones of the photometric calibration system of the RV Cass

No.	According to geometric measures of the disk		According to calibration at spectro-Chalonge	
	$\log \frac{I_i}{I_0}$ (1)	$\log \frac{I_{i+1}}{I_i}$ (2)	$\log \frac{I_i}{I_0}$ (3)	$\log \frac{I_{i+1}}{I_i}$ (4)
1	0		0	
2	0.124	0.124	0.124	(0.124)*
3	0.289	0.165	0.284	0.160
4	0.416	0.127	0.423	0.139
5	0.552	0.136	0.570	0.147
6	0.660	0.108	0.704	0.134
7	0.792	0.132	0.848	0.144
8	0.926	0.134	0.974	0.126
9	1.054	0.128	1.092	0.118
10	1.174	0.120	1.201	0.109
11	1.303	0.129	1.317	0.116
12	1.429	0.126	1.423	0.106
13	1.552	0.123	1.522	0.099

* This value was not deduced from measurements at the spectro-Chalonge. It is the value obtained from geometric measurements.

N. B.: The first two columns correspond to the values calculated according to the aperture angles of the sectors for the successive zones (measurements by Mr. Baillet—1970).

The next two columns are deduced by calibration of our system with the help of the UV spectrograph of Dr. Chalonge.

The values in column (4) are estimated at ± 0.005.

A slight dependence of $\log \frac{I_{i+1}}{I_i}$ on λ has been observed.

Here mean values are given for $3800 < \lambda < 4700$ Å.

Comparison spectrum

Normally, the comparison spectrum is the iron spark spectrum. Other sources available include:

— a Palladium arc,

— a Mercury + Argon lamp,

— a Neon lamp.

These lamps in their lamp housing can be interchanged immediately.

In order to obtain an iron spectrum illuminated independently of wave-length, part of the exposure is made with an aviol filter that cuts away the ultraviolet light.

The values concerning the decker are given in Paragraph II. 5 of the complete manual.

Use of a filter in the stellar beam

Movable filter in front of the slit

A filter of density 1 may be mounted on the fork that carries the reflecting prism for the comparison sources and which surrounds the stellar beam above the slit.

A very provisional mounting may also be made on this fork as a support. In this case, the visiting astronomer will have to bring his own gelatin filter.

Another filter can also be brought in front of the slit by means of a sliding support. This filter is passed once by the incident stellar beam, twice by the reflected beam used for guiding. A visitor may insert here his own filter, provided that it fits within a circle of 40 mm diameter. The density of this filter should not be more than 1 (this gives density 2 for the guiding).

The density of the neutral filters found on La Silla is of the order of 1.

In case the visitor wants to use his own filters he is asked to contact the staff in Chile as soon as possible in order to prepare the necessary supports.

Filter in fixed position behind the slit (not recommended)

The slit-lens cell permits the mounting of a filter behind the slit. This can be a gelatin or a glass filter. However, the solution given above (use of a movable filter in front of the slit) is much to be preferred.

Adaptable photographic camera

It is possible to take a photograph of the field of the spectrograph. This is done by removing the widening device and replacing it with a camera consisting of a 45° mirror and a 9 × 12 cm plate holder. Guiding is done by maintaining the image of the central object on the centre of the slit. In order to make this possible a central hole (ϕ = 10 mm) has been made in the 45° mirror. For this reason *photometric measurements will be quite impossible* on the plate, due to vignetting in the centre (central hole of the mirror) and on the outer parts (the mirror has been designed for a field of 50 mm diameter [= 7′]).

USEFUL DATA FOR OBSERVATIONS

Eyepieces.

The spectrograph is equipped with two eyepieces, one for locating the field and one for guiding.

— Wide-field viewer: field = 50 mm, that is, 7′ at the f/15 Cassegrain focus of the 152 cm telescope.

— Viewer for guiding: field = 22 mm, that is, 3′ at the same focus.

Slit orientation

The slit is pre-orientated in its cell. Usually the spectrograph is attached so that the slit is orientated east-west. The turntable permits, without any adjustment, orientation of the slit. (Note that this operation is long and uncomfortable.)

The field in the viewers is inverted in comparison with the field obtained directly in the telescope itself.

N. B.: The RV Cass is generally used at the Cassegrain focus of the 152 cm telescope (f/15).

The telescope is equipped with

— one finding telescope (Cassegrain) of 25 cm aperture. Its field is 50′,

— two wide-field refracting telescopes with a field of 2°.

Film

The spectra are formed on spectrographic KODAK film which is cut in sizes of 20 × 26 mm. Only emulsion II a-O is available at La Silla.

Dispersion, spectral range, resolution

The mean dispersion is 74 Å/mm for a spectral range extending from 3250 to 5000 Å, centred at about 4250 Å. (Maximum efficiency of the coated optics.)

The image of a 1.2″ slit on the sky (usual slit of 137 μ) is 18 μ; 1 Å on the film is approximately 14 μ; this gives a resolution of about 1.3 Å which is the resolution limit of 2 lines and corresponds to the II a-O emulsion grain (see Fig. 1). For the radial velocities, a displacement of 1 μ on the film corresponds to a radial velocity varying from 6.3 km/s (for 3500 Å) to 4.4 km/s (for 5000 Å).

The effect of the flexure has been measured and is less than 1 μ per hour. The small effect is compensated by taking the comparison spectrum twice, once at the beginning of the exposure and once at the end.

Exposure time

Figs. 2 and 3 give an idea of the exposure time with a good quality of seeing (1″ to 1.5″) and good transparency.

"Seeing" is here defined as the apparent diameter in seconds of arc of the image of a B or A star of 11th photographic magnitude, observed with the guiding eyepiece of the spectrograph.

It may be useful to keep in mind that one obtains a spectrum of:

— a 10th magnitude star in one hour (widening = 400 μ),

— a 12th magnitude star in three hours (widening = 250 μ).

Slit-width

The slit-width most generally used is 137 microns (1.2″ on the sky) which gives an image of 18 microns on the film.

The scale on the slit, at Cassegrain focus of the 152 cm telescope open at f/15, is:

1″ = 110 microns

or 9″ per millimetre

Other slits can be used; their widths are about 50, 115, 130, 242 and 300 microns. Their cells automatically ensure proper focusing.

The whole height of the slit may be used (48 mm = 7′ arc) for photometry.

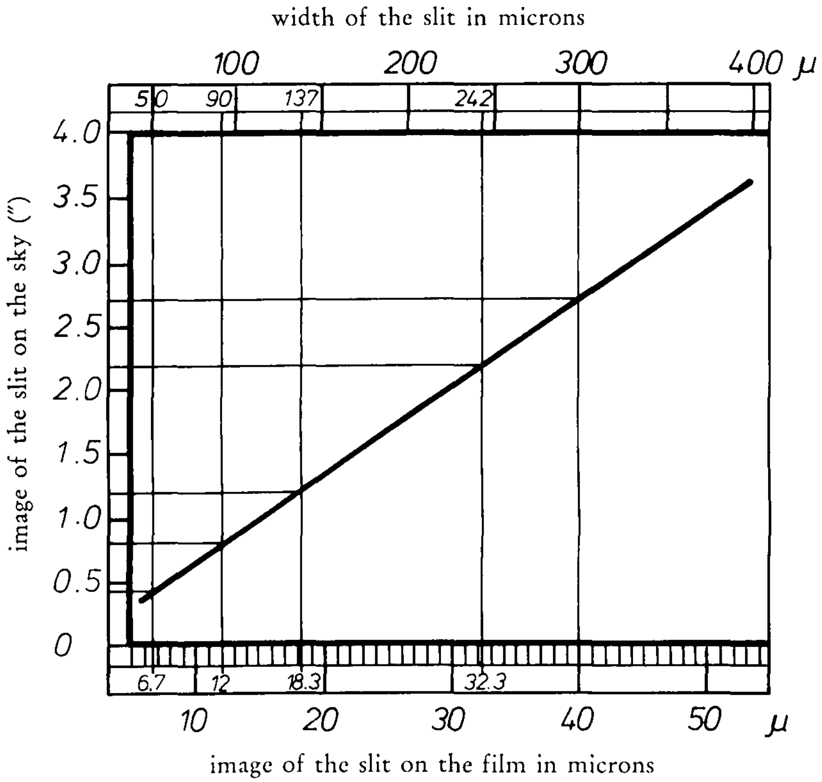

Fig. 1

Slit-height

The height of the spectra is defined by deckers (there are five at present); the following heights are possible: 60, 107, 200 250, 300, 400, 500, 600, 700, 750 microns and 1, 1.5, 2.0, 2.5, 3.0, 6 mm.

Instructions on how to use the decker will be given at La Silla.

The automatic rocking plate cannot be used for the heights of 60 and 107 microns. In that case, one has to use the fine motion of the telescope to widen the spectra.

Position of spectra on the film

Five to six spectra may be taken on one film, or two to three spectra plus one photometric calibration, or one to two photometric calibrations. All this is described in the instruction manual for the spectrograph which you will find in Chile. It is possible to develop up to 25 films simultaneously, which means about 100 spectra.

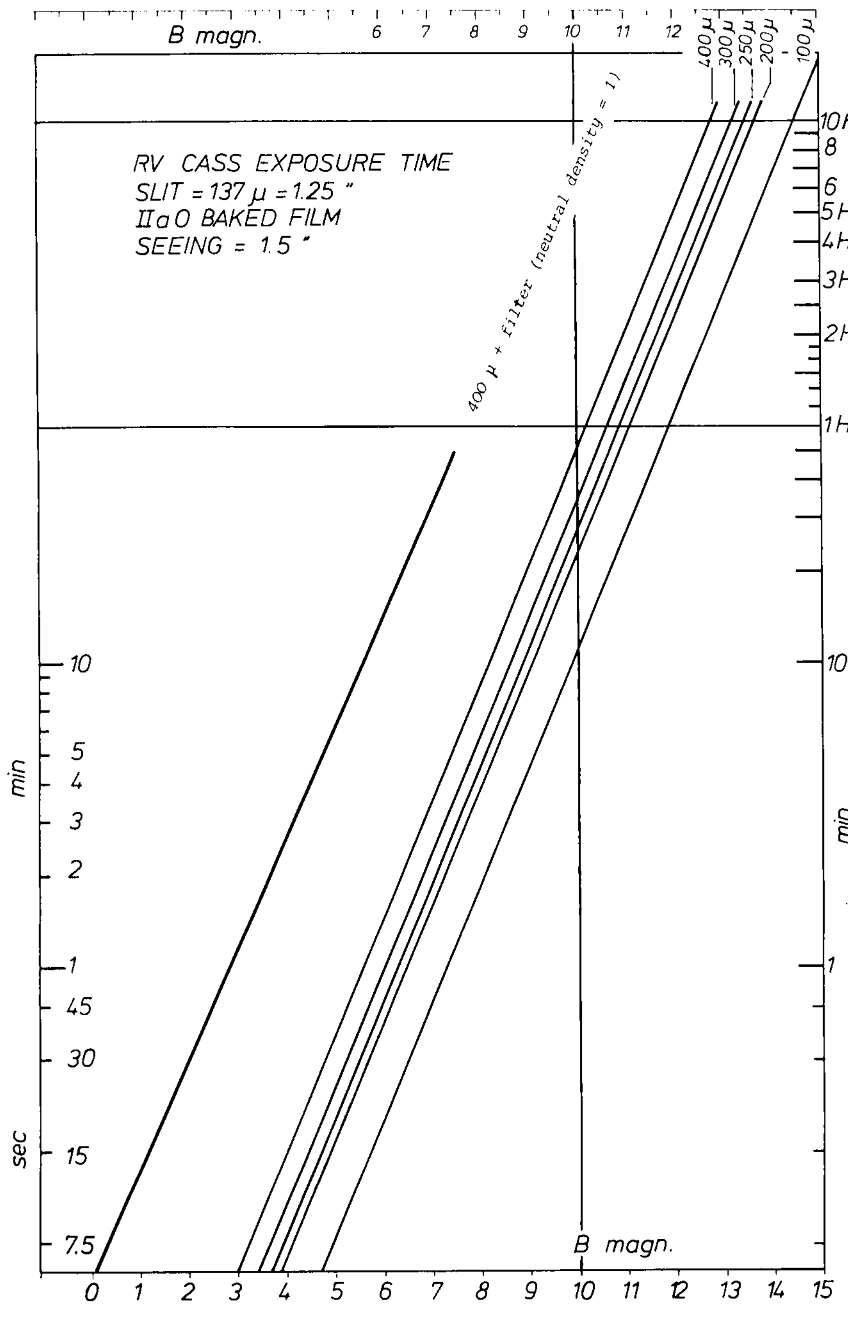
B magn.
6 7 8 9 10 11 12
400 μ
300 μ
250 μ
200 μ
100 μ
400 μ + filter (neutral density = 1)
RV CASS EXPOSURE TIME
SLIT = 137 μ = 1.25 "
IIa O BAKED FILM
SEEING = 1.5 "
10H
8
6
5H
4H
3H
2H
1H
10
min
1
10
5
4
3
2
1
45
30
15
7.5
sec
B magn.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Fig. 2.

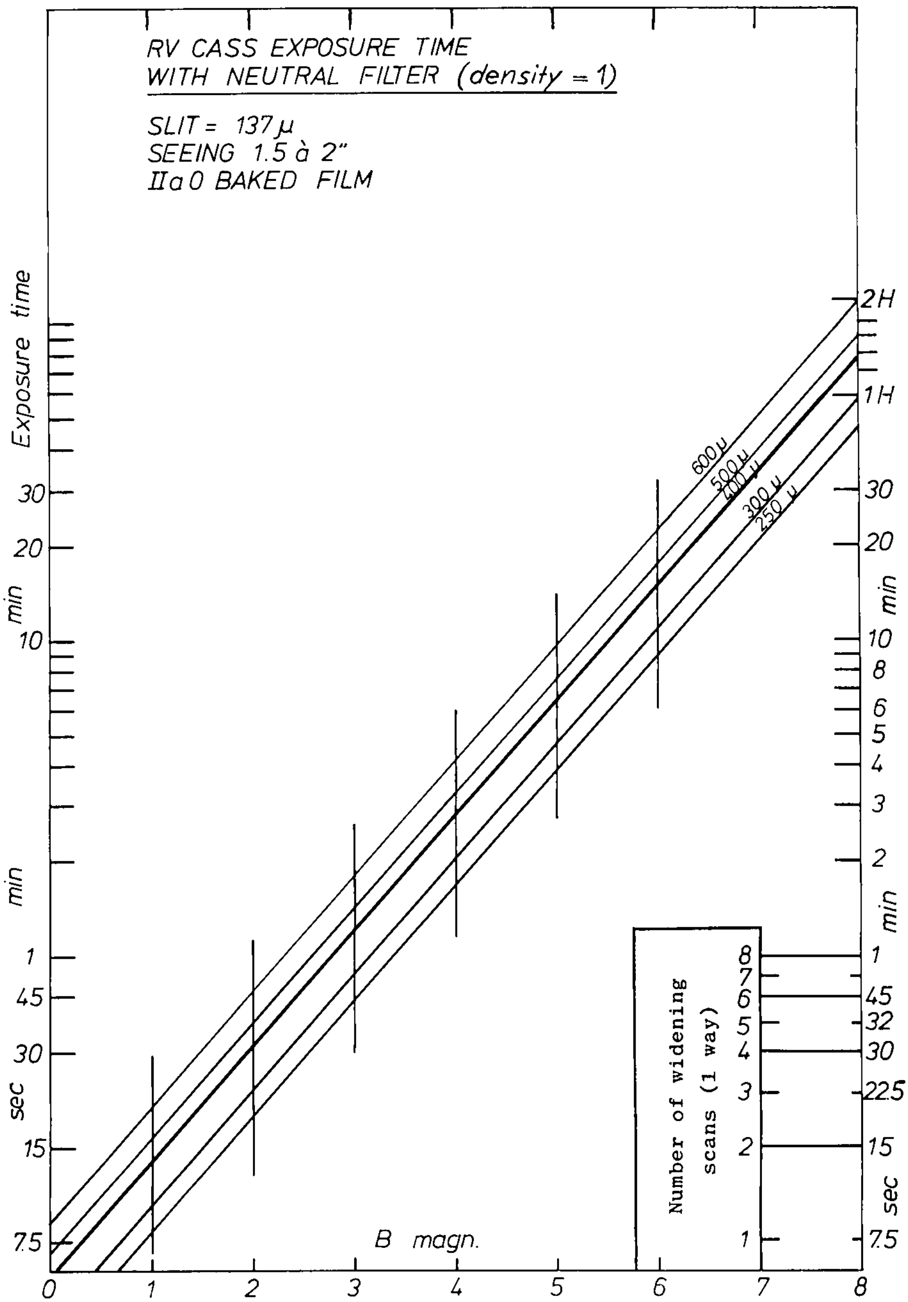
RV CASS EXPOSURE TIME
WITH NEUTRAL FILTER (density = 1)
SLIT = 137 μ
SEEING 1.5 à 2"
IIa 0 BAKED FILM
Exposure time
min
sec
2H
1H
600 μ
500 μ
400 μ
300 μ
250 μ
B magn.
Number of widening scans (1 way)
30
20
10
8
6
5
4
3
2
1
45
32
30
22.5
15
7.5
0
1
2
3
4
5
6
7
8

Fig. 3.

E. Maurice

Useful information for the reduction of measurements

In Santiago and on La Silla, machines and programmes are available for measurements of radial velocities and densities as well as for spectral classification.

References:

— "Un nouveau montage spectrographique." A. Baranne, 1965. Compte rendu à l'Académie des Sciences, **260**, pp. 3283—86.

— "Le spectrographe Cassegrain du télescope de 1,52 m." A. Baranne, E. Maurice, L. Prévot. Partie I. ESO Bulletin No. 7, September 1969.

— "Flexions d'un spectrographe." A. Baranne, E. Maurice. ESO Bulletin No. 7, September 1969.

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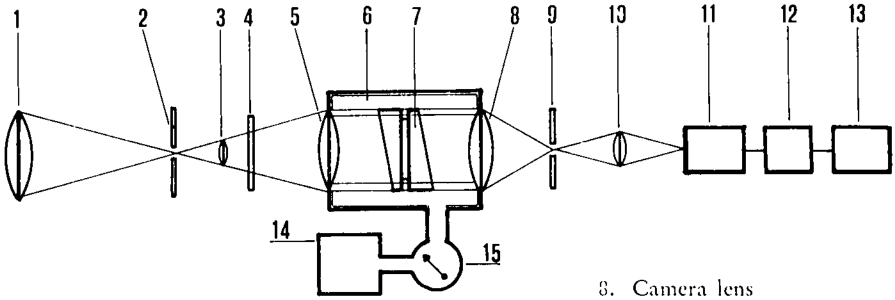
FABRY-PEROT EMISSION LINE SCANNER

James Rickard

Introduction

A photoelectric emission line scanner employing a pressure-scanning Fabry-Perot étalon has been developed and constructed at ESO/Chile. The basic design follows closely that of Vaughan (1967, Ann. Rev. Astr. and Astroph., **5**, 139). A scheme of the spectrometer is given in Fig. 1.



1. Telescope
2. Entrance diaphragm
3. Field lens
4. Order filter
5. Collimator
6. Pressure tank
7. F-P
8. Camera lens
9. Exit diaphragm
10. Relay lens
11. Channeltron PM
12. Pulse counter
13. Computer (or output)
14. CO_2 gas
15. Pressure regulator

Fig. 1.

A picture of the device attached to the 1.50 m telescope is shown in Fig. 2. The actual spectrometer was provisionally attached to the tripod assembly of the RV Cass spectrograph. This tripod was designed to hold a much heavier instrument in a three-point suspension; therefore the rather curious support arms around the middle.

A new finder-guider unit is presently being completed to support not only the F-P but also other Cassegrain instruments.

The instrument

A. The front end

1. Telescope

The spectrometer is matched to an f/15 entrance. Both the ESO 1.5 m and 1 m telescopes can be used as the light gatherer. Tests and initial programmes have been done using the 1.5 m telescope. For emission regions, such as planetaries and H II regions, nothing is gained in light input by using the larger telescope, when the image of the object is larger than the entrance diaphragm. However the angular resolution is higher and this is important for investigating internal motions in certain objects.

2. Entrance diaphragm

The largest entrance diaphragm has a diameter of 3.6 mm, which corresponds to 32″ of arc on the 1.5 m telescope and to 48″ of arc on the 1 m. The size of the largest diaphragm is determined by the expression: $R\ \Omega = 2\ \pi$ where R is the spectral resolution and Ω the solid angle of the entrance diaphragm as seen from the F-P étalon. In practice, this means that the entrance diaphragm seen through the F-P étalon has the same diameter as the central fringe. A larger diaphragm would degrade the resolution of the instrument. A smaller diaphragm, while providing higher angular resolution, cuts down on the light, with little or no increase in spectral resolution. Then the intrinsic resolution of the étalon itself is the limiting factor. As described by Vaughan (1967), one matches the two resolution limits to get maximum "throughput" or efficiency.

3. Field lens

A field lens is used to form an image of the primary mirror of the telescope on the collimator. This is necessary for accurate photometry, and to insure that all the light passes through the F-P étalon.

4. Order filter

This is an interference filter which has as small a bandwidth as can conveniently be manufactured. This permits light at the wavelength of interest to illuminate the F-P étalon. One would prefer that it pass light over the wavelength range of one or two orders, but this is hard to achieve in practice. If there is very little continuum radiation around the emission line of interest, the bandwidth of the order filter may cover many orders. This usually means an additional light gain for the instrument since narrow narrow-band filters generally have less peak transmission than slightly wider narrow-band filters. This filter is fixed in a rotating mounting to permit some wavelength tuning.

The central wavelength of the filter can be shifted to the blue by rotation. This is often used to look at calibration lines near the emission line of interest and to cover a larger wavelength range with the same filter. As an example, we have an Hα filter with $\lambda_0 = 657.0$ nm which is fine for the red-shifted Magellanic Clouds and which can be rotated to 656.3 nm for Galactic work.

B. The Fabry-Perot étalon and pressure tank

1. Tank and étalon holder

The pressure tank and étalon holder are of a special design and construction described by Vaughan and Münch (1966, Astron. J., 71, 184). These parts are temporarily on loan from the Hale Observatories through the kindness of Prof. G. Münch. The étalon holder is made of Invar to minimize misalignments arising from the thermal expansion and contraction.

2. Etalons

Two étalons can be used. One pair of plates is coated to cover the wavelength range 625 → 680 nm. The second pair covers 365 → 415 nm. The plates have

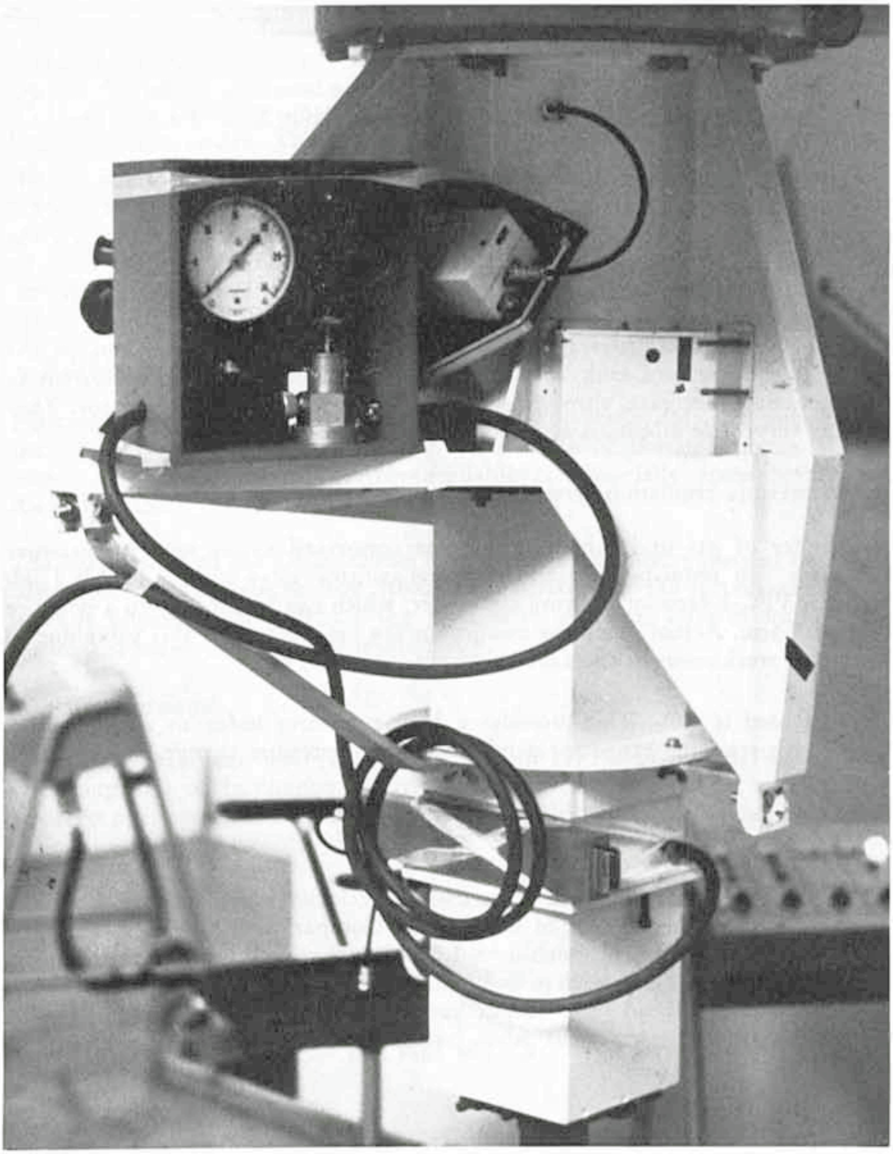


Fig. 2: The Fabry-Perot emission line scanner.

an outside diameter of 1.5 inches and a clear area of 1 inch. The reflective finesse for both étalons is 28.6 and they are antireflection-coated on the outer surfaces to maximize transmission. The plates are wedged to insure that any ghost reflections are not collinear with the interference image.

The plates are separated by three metal spacers which are gently squeezed between the plates. Spacers of 0.75 to 1 mm have been used so far. These provide a free spectral range (interorder distance) of about 2.2 to 2.8 Ä at Hα.

Adjustment of the parallelism of the plates is effected by three micrometre screws which are coaxial with the spacers. This adjustment can only be made at ambient pressure with the camera end of the tank removed. A check on the parallelism at other pressures, and as a function of time can be made by examining the symmetry of the profile of a comparison line, making sure that it always appears at the same pressure. The long-term stability is quite acceptable—some three to four hours between tunings. This is partly due to the fact that the pressure tank is not a gas flow device, but a closed system in which pressure decreases through an exit value in the pressure regulator. Thus there is very little vibration associated with slow changes of pressure.

3. The pressure regulation system

A cylinder of gas under high pressure is connected to an accurate pressure gauge via two reducing valves. The actual control valve is an Edwards High Vacuum VPC-I vacuum pressure controller, which can be used up to a pressure of over 4 atm. Actual observing conditions are limited to half this value due to structural weaknesses in the tank windows, couplers, etc.

The gas used is CO_2. This provides a high refractive index to allow a large wavelength scanning range for a relatively small pressure change. We have the equation:

$$\frac{\Delta\ \lambda}{\lambda} = \frac{\mu\ -1}{\mu}\ \Delta\ p$$

where μ is the refractive index. Note that the velocity range covered in a fixed pressure range is independent of wavelength. Comparing CO_2 with nitrogen or air we point out that CO_2 with $\mu = 1.00045$ will scan a velocity range 1.5 X larger than nitrogen (air) with $\mu = 1.00030$ for the same Δ p.

C. The back end

1. Exit diaphragm

The exit diaphragm is required to block any ghost images from reaching the photomultiplier. This diaphragm must be changed with the entrance diaphragm —the two are a matched pair, the size of the exit being reduced by the ratio 3 : 1 since the camera is f/5.

2. The relay lens

The relay lens forms an image of the exit diaphragm on the 1 mm cathode of a Bendix Channeltron BX 754 photomultiplier.

3. The detector

The Channeltron is mounted in a small plastic cylinder which fits inside a larger metal cylinder. This permits fine adjustments of the focusing of the relay lens. In addition, the entire mounting can be moved in X and Y to effect exact centering of the image on the small cathode.

The alignment is done by placing a bright star in the entrance diaphragm and moving the Channeltron housing around to maximize the signal. This alignment is critical for maximizing the instrument's sensitivity

4. Pulse-counter

Pulse-counting is used exclusively with the Channeltron PM. The pulse-amplifier / discriminator can be seen taped to the side of the instrument. We are using the photon counter system available commercially from Solid State Radiation, Inc.

The dark count of the Channeltron is less than 5 ct/s under normal observing conditions without any cooling. Absolute calibration of the instrument in flux units is accomplished by observing a series of standard stars of known flux during the night, as in normal photometry.

5. Data acquisition

During the tests and observing programmes in 1971 a provisional data system consisting of a MHz counter attached to a printer was used. In mid-1973 we put into operation a small computer data acquisition system to speed up observations.

Conclusions

The initial observing programmes were concerned with the Hα emission line. The cluster-H II region IC 2944 was studied as well as 28 southern planetary nebulae. The instrument is versatile and can be used for many emission lines. One need only change the narrow-band order filter made for the desired line and use the proper étalon.

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IMAGE TUBE CAMERA

James Rickard

Introduction

An image tube camera, incorporating an ITT F-4708 image intensifier, is now in general use at ESO/Chile. The camera was designed and built in Santiago, and is used in conjunction with the direct-photography camera built by C. Zeiss for the 1.52 m telescope.

Image tube

The ITT F-4708 image intensifier is a single-stage electrostatically focused tube with both fibre-optic entrance and exit windows. The cathode is of the S-25 extended red type so that the tube has a near infrared response to about 850 nm. The ultraviolet response is limited by the UV absorption in the fibers of the entrance window to approximately 385 nm.

The cathode and screen are 40 mm in diameter with a 1 : 1 magnification. Pincushion distortion, common with electrostatic intensifiers, is considerable outside a diameter of 30 mm. There are also variations in cathode sensitivity which appear to be a function of radial distance, although the background itself is much more uniform.

Power supply

The tube and its high voltage supply are encased in an electrically-insulating silicon rubber potting compound. The power supply operates on an external voltage of from 2.45 to 2.75 VDC. The actual operating voltage is chosen to match the tube. There is a compromise between resolution and background level which is a function of the operating voltage. This is determined empirically by testing the tubes at the telescope with a variety of voltages.

The external power supply consists of two 1.5 VDC "D" cells used in flashlights. These are mounted in a battery-holder which contains a rheostat to adjust the voltage. The current is passed through an ammeter of high precision for the exact settings required. (The holder-rheostat assembly was purchased from U.S. Army surplus.)

Resolution and background

The limiting resolution of the intensifier, i.e. measured at 5 % level of the modulation transfer function, is 50 → 55 line pairs per mm. This declines to 40 → 45 lp/mm 5 mm from the edge. In practice, this imposes no limitation when it is used as a direct photographic device, since the scale of the 1.5 m telescope is 9″/mm or 1″ = 110 μm. Hence any image tube with a resolution greater than 10 lp/mm would be sufficient to resolve stellar images at the 1.5 m telescope.

The background of the tube is low enough to permit exposures up to 1.5 hours. Normally, the sky is five to ten times higher. The sky and the tube background are about equal when a filter of 50 Å is used. Thus for narrow-band filters one is background-limited, while for broader band work the sky is always the limiting factor. For photos taken without a filter—i.e. using the integrated light from 385 to 850 nm—sky limits the exposure time to three to five minutes.

Gain

The "gain" of the tube is a difficult parameter to measure since it must be specified with respect to something else. When compared to II a-O plates, the intensifier produces the same image blackening about 15 times faster, but the II a-O plate is superior for photographic photometry and not subject to the same type of distortion or calibration difficulties. The gain in the red and near-infrared is, of course, much higher.

Often one is happy to get any photo at all, in spite of calibration difficulties. There are many applications where exact photometric calibrations are unnecessary—e.g. identification of radio sources, faint galaxies, emission line structure in planetaries, etc.

The camera

The camera consists of three sections: the mounting plate, the tube-holder, and the plate-holder. The parts are constructed of electrically-insulating plastic to avoid problems of corona and electric arcing. The tubes originally purchased were of the screen-grounded type. In the future, tubes with the reversed configuration—cathode-grounded—will be used, since these seem to have a lower background emission. The camera was designed to accommodate both types. Both the cathode and screen are electrically-insulated and floating.

1. The mounting plate is designed to fit in place of the regular plate-holders of the Zeiss camera. Thus the normal set of filters used for direct photography can be used with the image tube camera.

2. The tube-holder is a square box with two end-plates cut to fit the cylindrical shape of the intensifier. The electrical connections to the tube extend through a small hole in the side of the box. Six sliding clips secure the plate-holder to the back of the tube-holder. Fig. 1 shows the mounting plate and tube-holder separated from the plate-holder. The screen is visible. Fig. 2 shows the complete camera.

3. The plate-holder is designed to press 6 × 6 cm glass plates in contact with the fibre-optic screen. Since the phosphor is of the P-20 type (maximum brightness at 530 nm) II a-D plates are used. A small metal mounting-block holds the plate on three sides; two of which are fixed, the third is a spring-

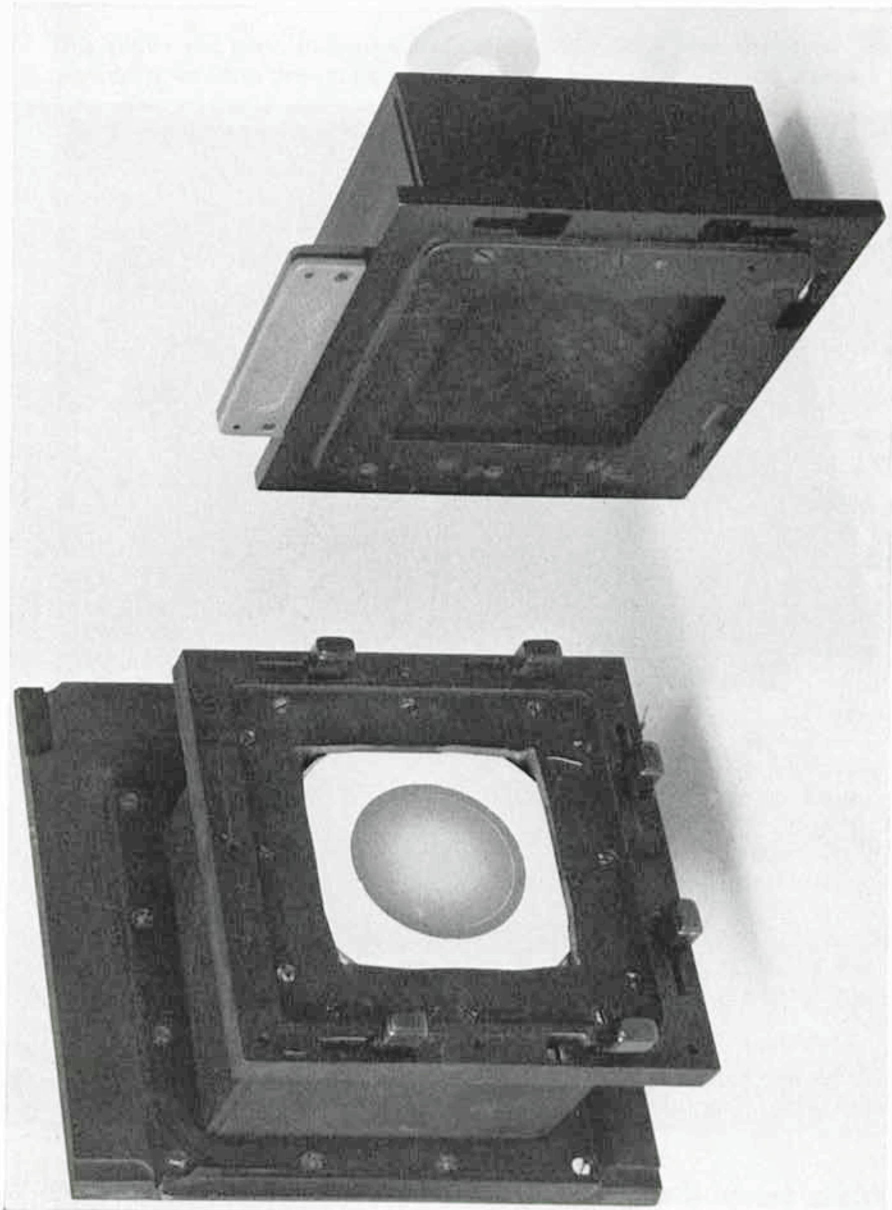

Fig. 1.

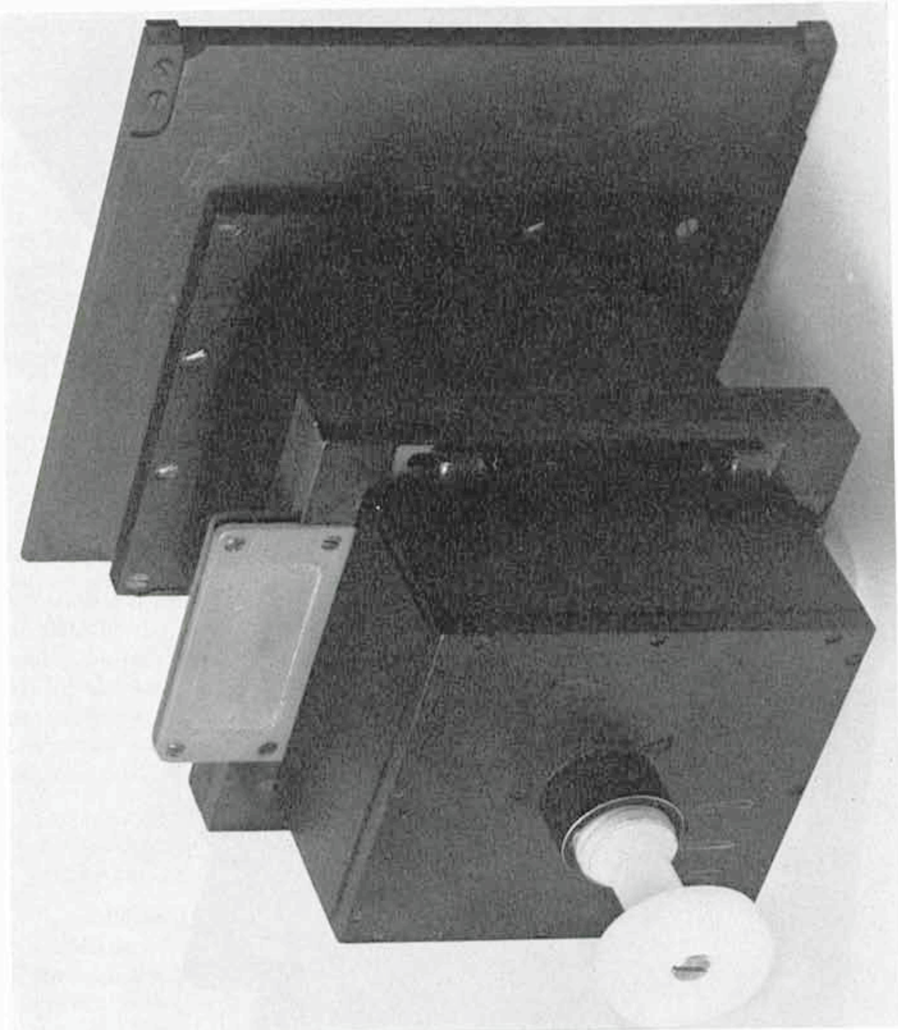

Fig. 2.

loaded clip. Fig. 3 shows the open plate-holder. The metal mounting block is attached to a piece of polyurethane foam 1 cm thick. (The type used to make mattresses.)

This allows the plate sufficient freedom to align itself with the screen and provides a uniform pressure to keep the plate in contact with the screen.

The plate is moved forward and backward, to and from the screen, by a screw transport seen clearly in Fig. 2.

Typical night's use

We shall finally describe the typical procedure for using the image tube camera at the 1.5 m telescope.

1. The entrance and exit windows must be washed with alcohol and cotton before the image tube is mounted on the Zeiss camera. The entrance window must be washed under low light-level conditions (rule of thumb: about as much light as is given by a candle at a distance of 4 m) and protected from all other light. Pieces of dust or cotton can be removed with a camel hair brush.

2. The tube is mounted on the Zeiss camera and the electrical connections are made. With the dome in complete darkness, the voltage can be turned on and slowly brought up to the nominal current for the particular tube in use.

3. All lights in the dome must be extinguished, including all pilot lights and indicator lights on the control panel. During plate-changing or moving the telescope, lights of a low level are allowed as long as there is a filter in place in the camera and the shutter is closed. The camera is sufficiently light-tight to prevent damage under low light level conditions.

4. The intensifier and telescope are focused visually. This is done by locating a bright star ($8^m \rightarrow 10^m$) and focusing the telescope to give an image of minimum size on the screen. Generally a 10 X magnifying glass is used to observe the star. The focus is slightly different for different filters. So one must focus through each filter. Normally it is sufficient to check the focus once an hour.

5. Then the area of sky to be photographed is centred on the screen and a convenient guide star is chosen in the guiding microscope. Thereupon, the shutter is closed.

6. The screen is brushed lightly with a camel hair brush to insure that no dust or foreign matter will scratch it or prevent good contact when the plate is pressed against it.

7. The plate-holder is hooked in position. The dark slide is opened, and the plate is moved into contact by screwing the handle clockwise.

8. The exposure is started and stopped by opening and closing the shutter on

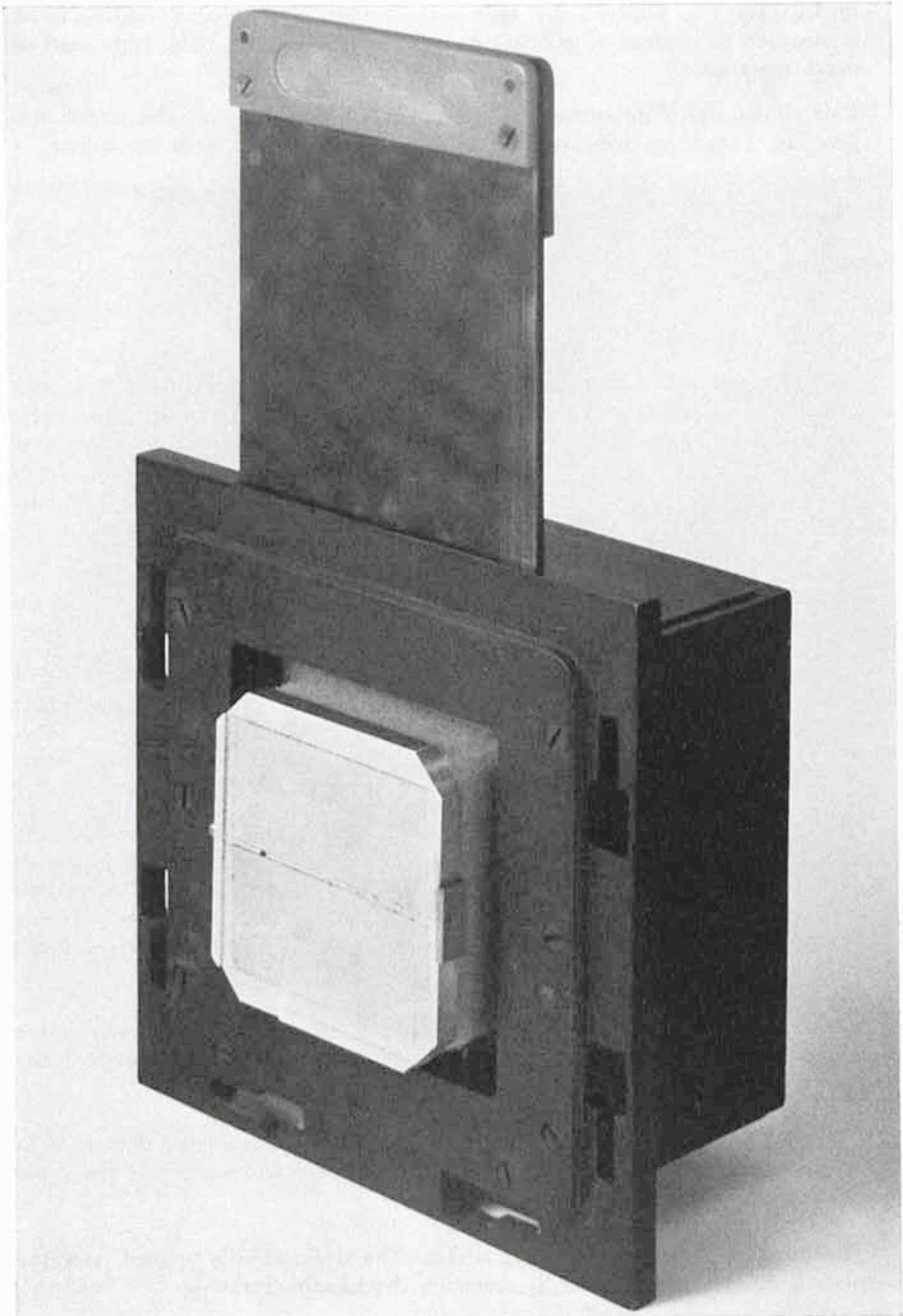

Fig. 3.

the Zeiss camera. Guiding during exposure is best done by turning the X-Y screws on the Zeiss camera.

9. The plate is moved away from the screen by turning the handle counter-clockwise. The dark slide is closed and the plate-holder unclipped and removed from the tube-holder.

Additional exposures are made by repeating steps 5 through 9.

At the end of the night the voltage is turned off and, after waiting 5^m, the tube can be removed from the Zeiss camera under dark conditions. The protective cover is placed over the cathode and the tube stored for the next night's use. The two flashlight batteries in the power supply should be replaced each night. The used ones still have plenty of life and are used in flashlights during the night.

The cutting and loading of the plates for the plate-holders are done by a qualified night assistant. He takes special precautions to prevent glass-chips from sticking to the plates. These could scratch the fibre-optic screen or prevent good contact.

At present we have two image tube cameras of the type described above, and there are six plate-holders to insure rapid plate-changing.

The annexed photos have been taken by the author with the image tube camera.

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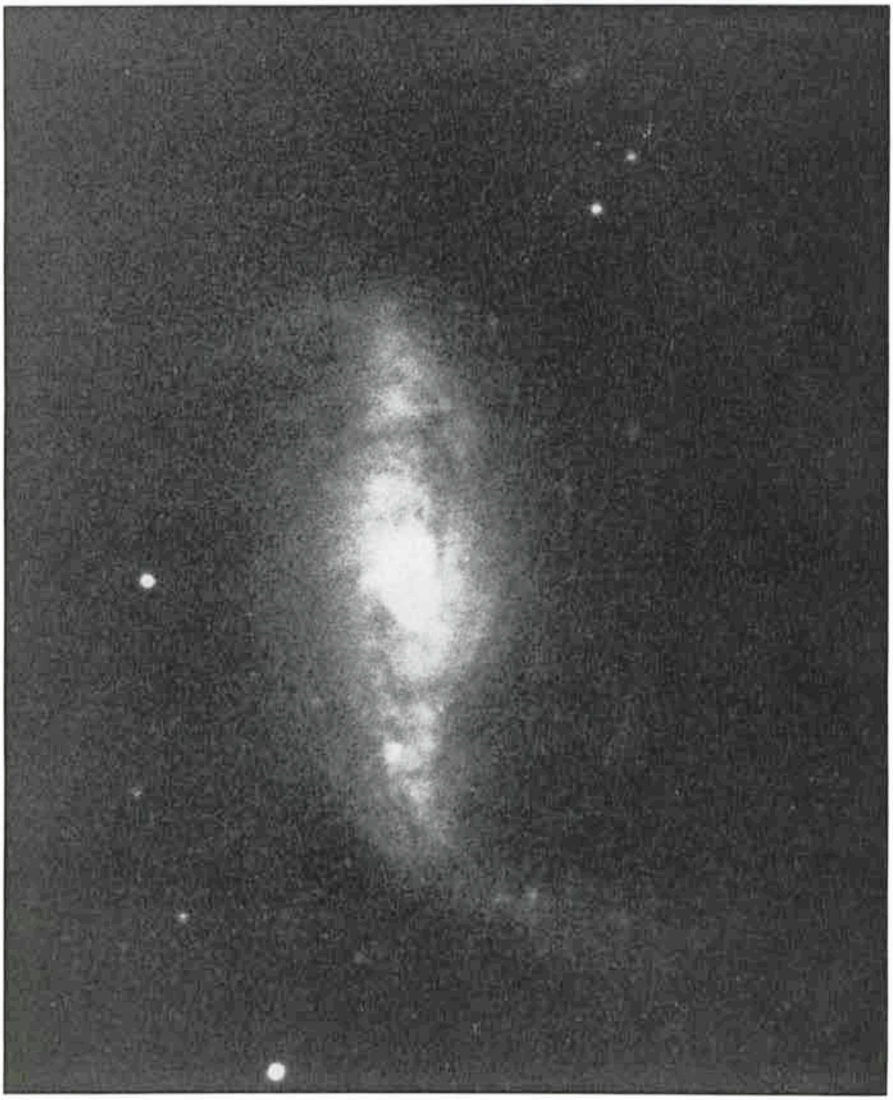
Photo 1

M 20; R-61; BG-28; 1 m

Photo 2



NGC 7552; R-124; no filter; 1 m; 30^s

Photo 3

NGC 1365; R-186; no filter; 1^m

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