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INFRARED PHOTOMETERS

Infrared Photometers

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Chapter 1

Introduction

The Infrared Photometers at the 3.6 m, 2.2 m and 1.0 m telescopes are used with the same data acquisition program (IRA) for doing:

- Photometry in a selection of broad-band filters between 1.2μ and 25μ .
- Narrow band spectrophotometry using circular variable filters (CVF) between 1.4μ – 5.2μ and 8μ – 14μ .
- Mapping with both broad band filters and CVFs.

Two detectors are available which can be mounted simultaneously on the common photometer mounts:

- InSb (photovoltaic) in the 1.2μ – 5μ range (cooled by solid N_2).
- Bolometer for 2.5μ – 25μ range (cooled by liquid He).

Only one of these detectors can be used at a given time. Switching detectors requires a beam diverter mirror and is a straight forward operation. In general, however, it is found that employing the same detector for the whole night leads to more efficient use of observing time.

Day-time observing, even in the infrared, is not as efficient as during the night-time (increased pointing and guiding difficulties, generally degraded seeing, higher background, etc.). Sunlight on any part of the telescope **should be strictly avoided**. Past experience shows that an efficient observer with a suitable program may work from 5–6 p.m. until 10–11 a.m., i.e. at most a total of 16–18 hours.

Some parts of this manual have been greatly influenced or taken from preliminary drafts manuals written by A. F. M. Moorwood and A. Van Dijsseldonk.

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

Chapter 2

The 1 m photometer

2.1 Optical/mechanical configuration

Figure 2.1 shows a schematic representation of the optics as used at the 1 m telescope. The mechanical mount which supports the two detector units contains an off-axis elliptical mirror that converts the $f/13.5$ telescope beam to $f/35$ and forms an image of the secondary mirror on the small flat mirror. This flat mirror can be “wobbled” to provide sky chopping through any angle of up to $2.5'$ (peak to peak) on the sky. It also has a central hole, sized to match the central obscuration of the telescope, behind which is located a spherical mirror whose center of curvature falls on the diaphragm wheel inside the detector cryostat. This mirror reduces the background radiation from the central obscuration which would otherwise be seen by the detectors. The central position of the wobbling mirror can be adjusted to cancel any chopping offset.

The last mirror in the photometer mount is the 45° beam diverter that can be rotated to direct the input beam to the required detector.

2.2 Eyepieces and guiding

Eyepieces are provided in the photometer mount, one for each detector. Their use involves manual operation of a knob which rotates two mirrors into position.

It is important to remember that these mirrors must be moved out of the beam before using the detector. The field of view of these eyepieces is $\simeq 1.75$ arcmin.

An eyepiece for guiding is also provided in the mount. It looks at a 45° mirror in the $f/13.5$ beam which has a central hole to allow the beam to pass through at maximum chopping amplitude. The eyepiece can be driven in X and Y via the control box which has digital position displays. The total guiding field is 22.5×22.5 arcmin² minus the circular central hole that has a diameter of $10'$.

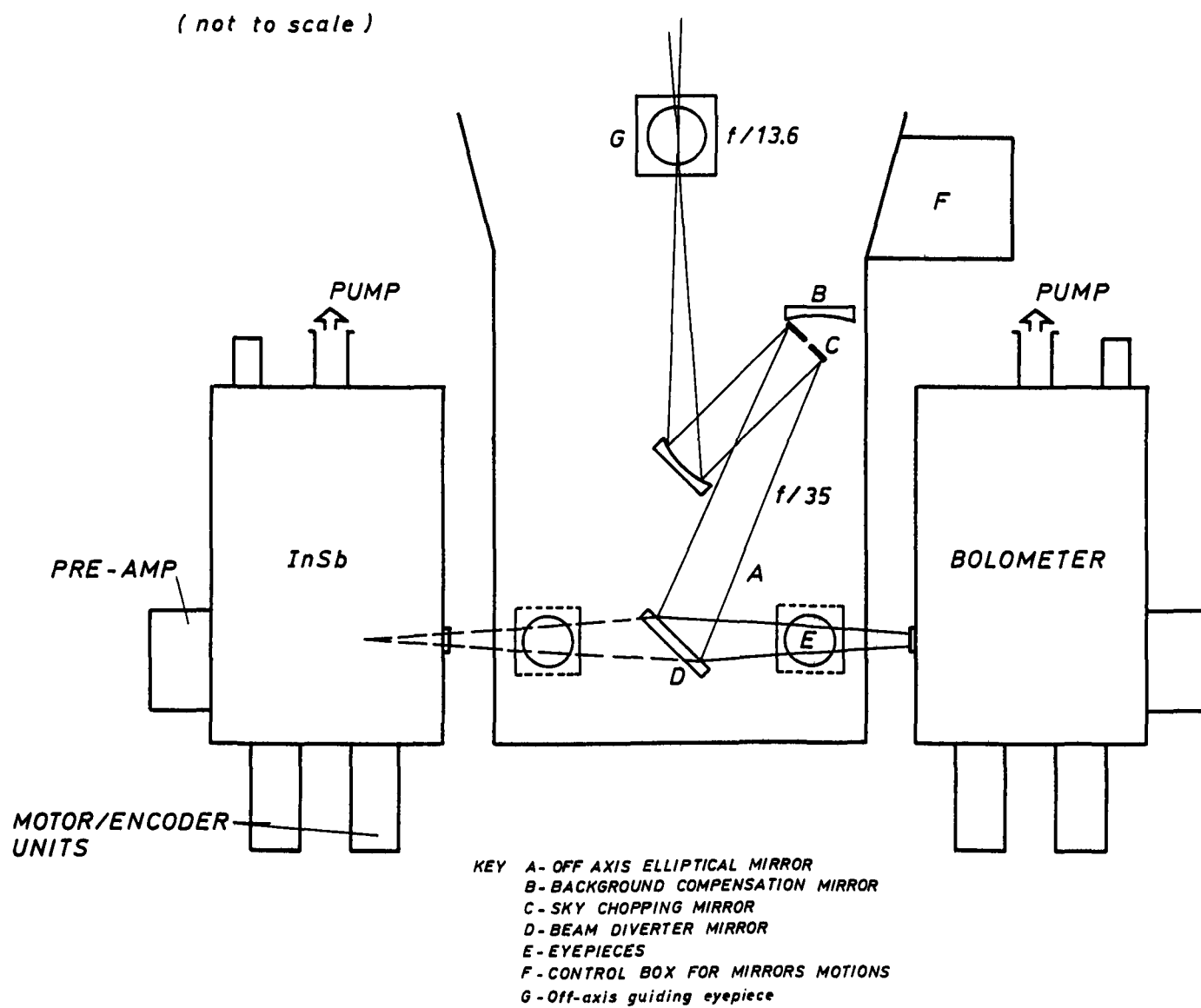


Figure 2.1: Schematic representation of f/35 IR photometer (1 m)

The guiding eyepiece field is $\simeq 5$ arcmin. The magnitude limit which can be seen is $V \sim 14$ in night-time and $V \sim 5$ in day-time. This image in the guiding eyepiece is not chopped, but the detector eyepiece fields are chopped.

The motions of all these mirrors are controlled by “press-release” knobs located at the control box on the bolometer side of the photometer. When switching from one position to the other, one must first *release* the pushed-in button and then *press* the other one.

2.3 Sky chopping

The f/13.5 focal plane chopper consists of a small flat mirror mounted on a commercial scanner (G100 PDT General Scanning Incorporated + Scanner Control CCX100). The scanner control is mounted in the rack below the photometer. It provides square wave and ramp options, selected by means of a switch in the front panel.

The three critical parameters for the observer are: FREQUENCY, AMPLITUDE, and CENTER POSITION.

- **FREQUENCY:** can be selected using a wave generator signal transmitted to the control room. The “normal” settings are 8 Hz for the InSb and 13 Hz for the Bolometer. The observer *should not* change these values.
- **AMPLITUDE:** can be adjusted on a bright star as follows:
 1. Acquire a bright star in the eyepiece
 2. Set telescope offset to desired throw amplitude. This is normally in RA but can in principle be any orientation.
It is important to check that the Cassegrain rotator is correctly set.
 3. Beamswitch manually (using the handset) while adjusting the chopper throw (knob “ATTENUATION” on Scanner Control) until the two spots alternatively fall on the center of the cross-hair.
- **CENTER POSITION:** affects the DC digital offset (and also the beam position for the two detectors). In order to minimize the offset, proceed as follows:
 1. Move the star $> 20''$ away in the direction orthogonal to the chopper direction.
 2. Check the DC offset in one of the broad band filters with $\lambda \geq 3.8\mu\text{m}$ using a large diaphragm (use lock-in).
 3. If the level is too high, adjust using the knob “DC LEVEL” on the scanner control.

During tests the level of DC offset has not generally caused problems. It may prove necessary to accept some offset, however, if the IR beam is required to be close to the center of the center field probe monitor. The setting of the center position is usually made by IR operators but the observer may need to adjust it during his/her run.

Chapter 3

The f/35 chopping secondary system at the 2.2 m telescope

3.1 The f/35 system

The standard set up for infrared photometry and CVF spectrophotometry at the 2.2 m telescope comprises:

- The f/35 chopping secondary mirror which is supported by the infrared top ring and spider assembly.
- The f/35 photometer adaptor which contains the TV acquisition and guiding system.
- Several detector units that can be attached to the photometer adapter (InSb and bolometer).

The operation of the chopping secondary and the adaptor are controlled via the programs CHOP2 and F35 respectively from a single HP 2645 terminal in the control room. Data acquisition and control of the detectors is performed via two separate HP terminals using the program IRA described in Chapter 8.

Most commands can be entered either via softkeys or by typing the name. Some parameters (e.g. chopping amplitude and frequency, guide probe speeds) are entered via forms.

The HP terminal displays: i) the active softkey menu; ii) the status of the chopping secondary and the photometer mount; iii) the name of the active program (CHOP2 or F35); iv) a space for typed commands and HELP messages.

Note

F35 commands are not recognized when CHOP2 is active and vice versa

3.2 Chopping secondary

This comprises a 21 cm diameter f/35 mirror attached to a unit which provides for focus and rotation as well as chopping. Control is under the program CHOP2. If F35 is displayed then CHOP2 can be activated via a softkey. The CHOP2 softkey menus are given in fig 3.1. The parameters to be set are described below.

3.2.1 Focus

This key selects the menu with commands to drive the mirror in both directions at either fast or slow speeds. The focus encoder reading is updated on the display only after the softkey is released.

3.2.2 Rotator

This rotates the secondary mirror unit and hence the chopping direction on the sky. Operation is analogous to Focus. The usual procedure is to chop in R.A.

3.2.3 Chopper set-up

This key selects a menu with several options: **LIST DISC SET-UPS** gives a list of 10 optimized chopper setups (frequency and amplitude). It is recommended to use one of these setups; this is done by using **RESTORE SET UP**. A **NEW SET UP** can also be made. Here, the amplitude (arcseconds on the sky; maximum = 100"), the chopping frequency (in Hz, usually about 8 Hz for the InSb detector and 13 Hz for the Bolometer), the focus (encoder units), and the rotator (degrees, 0 degrees is east-west) are entered by filling the form that appears on the screen. Fill the appropriate spaces using the TAB key to step the cursor and press "ENTER" to send the values to the computer.

After entering a **NEW SET UP** it is recommended to **OPTIMIZE AND STORE** this waveform. This operation will last about 8 minutes so this should preferably be done at the beginning of the run and *only if none of the available standard set-ups are suitable*. The **STATUS** key will update the display and should always be used after an **OPTIMIZE AND STORE** command and after a **RESTORE SET-UP** command.

CHOPPER generates a new menu containing the **OFFSET** commands and the commands used to activate **CHOPPER ON** or to stop it in different positions: at the center — **STOP AT OFFSET** —, at the positive beam — **STOP AT BOTTOM** — or at the negative beam **STOP AT TOP**.

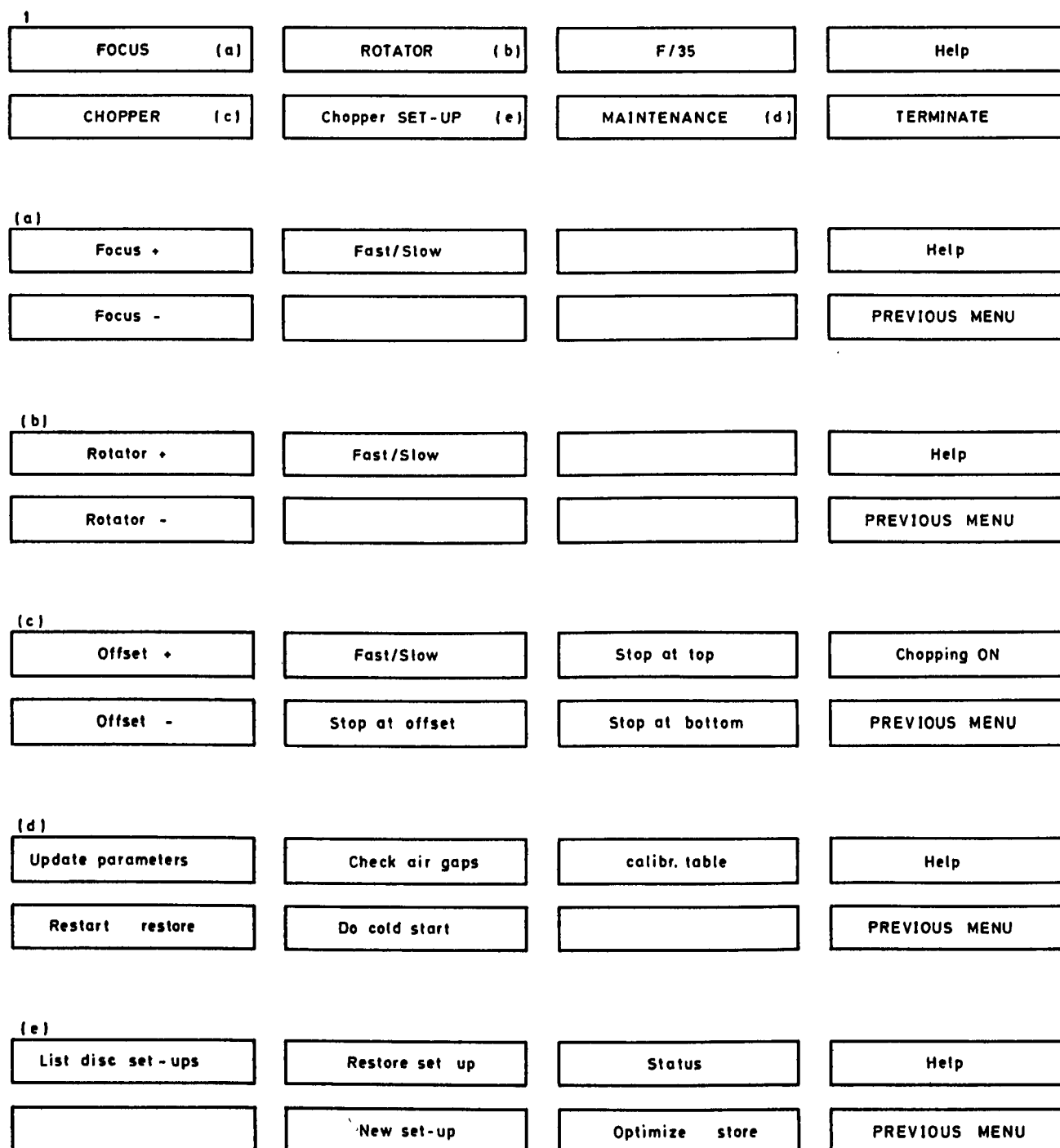


Figure 3.1: CHOP2 softkeys (2.2 m)

The **OFFSET** keys allows adjustment of the mirror center position to cancel any chopping offset signal. The procedure is to chop on empty sky and press **OFFSET +** or **OFFSET -** until signal is zero.

3.2.4 **MAINTENANCE**

This key generates a menu with the commands to set-up the system parameters and do (simple) troubleshooting. The **CALIBRATION TABLE** form is filled to give the correspondence between squarewave and amplitude/encoder units, the encoder units value for the rotator at 0 degree, and the correspondence between the degrees to rotator/encoder units.

The **UPDATE PARAMETER** key selects a form that allows setting-up:

- The system installation parameters (such as telescope identifier, telescope scale, cartridge number for data files, CAMAC LU and CAMAC station for kinetics interface).
- The offset and amplitude calibrations (same as **CALIBRATION TABLE**).
- The initialisation/set-up parameters (such as amplitude, frequency, rotation, focus, offset).

If some problem occurs with the chopper, a command may not be executed and an error message will be displayed asking to **CHECK AIR GAPS** or to **DO A COLD START**.

As the cold start procedure takes about 25 minutes, it is advisable to **never use this softkey without prior consultation with the IR operations group**. **CHECK AIR GAPS** and/or **RESTART and RESTORE** will, in most cases, solve the problem.

Chapter 4

The f/35 chopping secondary system at the 3.6 m telescope

4.1 The f/35 system

The standard set up for infrared photometry, CVF spectrophotometry and speckle interferometry at the 3.6 m telescope comprises:

- The f/35 chopping secondary mirror which is supported by the infrared top ring and spider assembly.
- The f/35 photometer mount which contains the TV acquisition and guiding system.
- Several detector units which can be attached to the photometer mount (InSb and bolometer photometer/spectrophotometers, InSb speckle interferometer).

The operation of the chopping secondary and the adapter are controlled via the programs CHOPR and F35 respectively from a single HP 2645 terminal in the control room. Data acquisition and control of the detectors is performed via two separate HP terminals using the program IRA for photometry (chapter 8) or IRK (c.f. IR Speckle Manual).

Most commands can be entered either via softkeys or by typing the name. Some parameters (e.g. chopping amplitude and frequency, guide probe speeds) must be entered via forms.

The HP terminal displays: i) the active softkey menu; ii) the status of the chopping secondary and the photometer mount; iii) the name of the active program (CHOPR or F35); iv) a space for typed commands and HELP messages.

Note

F35 commands are not recognized when CHOPR is active and vice versa.

4.2 Chopping secondary

This comprises a 33 cm diameter f/35 mirror attached to a unit which provides for focus and rotation as well as chopping. Control is under the program CHOPR. If F/35 is displayed then CHOPR can be activated via a softkey. The CHOPR softkey menus are given in fig. 4.1. The parameters to be set are described below:

4.2.1 **FOCUS**

Pressing the **FOCUS** softkey selects the menu from which the mirror can be driven in both directions at either the fast or slow speeds through **FOCUS +/-** and **FAST/SLOW** keys. The focus encoder reading is updated on the display only when the softkey is released.

4.2.2 **ROTATOR**

This rotates the secondary mirror unit and hence the chopping direction on the sky. Operation is analogous to FOCUS. The usual procedure is to chop in R.A.

4.2.3 **WAVEFORM SET UP**

This generates a form for entering the chopper parameters:

WAVEFORM	:	(Square-SQ for photometry)
AMPLITUDE	:	(Arcsec on sky up to 120")
FREQUENCY	:	(Chopping frequency in Hz, usually 8 Hz)

4.2.4 **CHOPPER**

This leads to a menu containing the **OFFSET** commands and the commands used to activate the chopper — (**CHOPPING ON**) — or stop it at different positions: at the center — **STOP AT OFFSET** —, at the positive beam — **STOP AT BOTTOM** — or at the negative beam — **STOP AT TOP** —. Usually **STOP AT BOTTOM** is used during optical acquisition to avoid confusion in the TV field and to center the positive beam. The **OFFSET** key allows adjustment of the mirror center position to cancel any chopping offset signal. The procedure is to chop on empty sky and press **OFFSET +/-** until signal is zero.

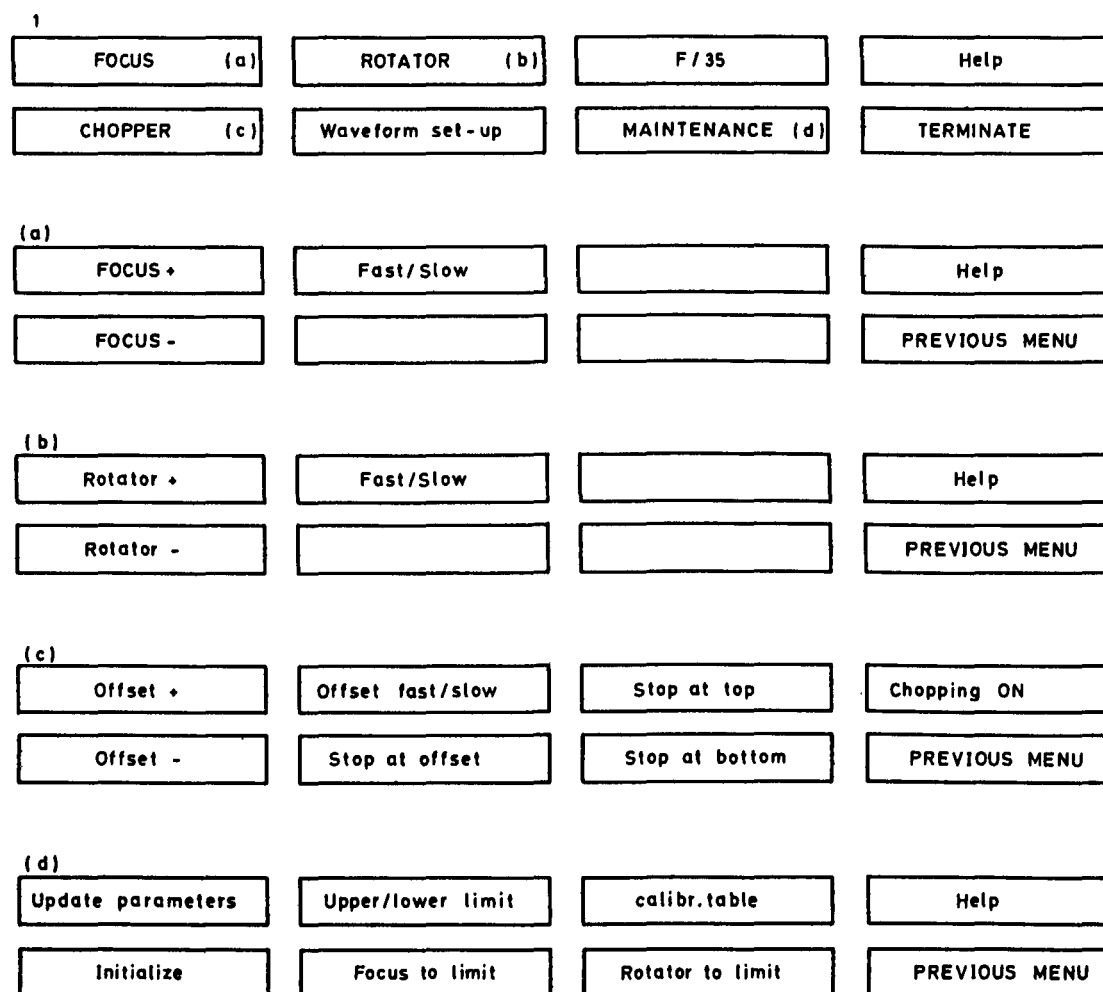


Figure 4.1: CHOPR softkeys (3.6 m)

4.2.5 MAINTENANCE

This key generates a menu with commands to set the focus and rotator values to their **UPPER/LOWER LIMITS** — **FOCUS TO LIMIT** — **ROTATOR TO LIMIT**. The **CALIBRATION TABLE** sets the correspondence between the voltage applied to the chopper and the chopping amplitude in arcsec. In case of (simple) troubleshooting, it can be necessary to **INITIALISE** the motors of the chopper.

The **UPDATE PARAMETERS** key selects a form that allows setting-up:

- The system installation parameters (such as telescope identifier, telescope scale, cartridge number for data files, CAMAC LU and CAMAC station for kinetics interface).
- The offset and amplitude calibrations (same as **CALIBRATION TABLE**).
- The initialisation/set-up parameters (such as amplitude, frequency, rotation, focus, offset).

Chapter 5

The f/35 photometers/adapters at the 3.6 m and 2.2 m telescopes

5.1 Optical arrangement

The f/35 photometers/adapters at the 3.6 m and 2.2 m telescopes are identical. Fig. 5.1 shows a schematic diaphragm of the photometer. The infrared beam is directed to either of the two detectors by a 45° dichroic mirror. Although not shown in fig. 5.1, there are in fact separate dichroics for the two detectors. These are supported on arms so that the centre of the field is either unobstructed (for acquisition of faint objects) or occupied by the appropriate dichroic mirror. The acquisition/guiding system employs a fixed TV camera which views the field via one of two objectives, a small flat mirror, and a field mirror in the focal plane of the telescope.

The two objectives give instantaneous fields of view of $3'9'' \times 5'8''$ and $6'3'' \times 9'5''$ at the 3.6 m and 2.2 m telescopes respectively, in **LARGE FIELD**, $1' \times 1'6''$ and $1'6'' \times 2'4''$ in **SMALL FIELD**. By tilting the small flat guide probe mirror these fields can be moved over the full $9'5''$ or $15'6''$ range. An optical cross is projected onto the TV camera. This cross has a “gap” in the center of $3'' \times 3''$ at the 3.6 m and $5'' \times 5''$ at the 2.2 m telescope.

The camera normally used is a Bosch ISIT sensitive only up to 8500 Å; various filters can be positioned in front of the TV cameras.

5.2 Acquisition and guiding

It is important to note that the same TV camera is used for center-field viewing and for offset guiding. During acquisition, the **GUIDE PROBE** must be at its center position. This position is determined and stored before the start of observations such that the center of the optical cross is coincident with the infrared beam center (see below). As the center field can be viewed either directly or through the dichroic, there are in fact two center field positions per detector (because the dichroics introduce a shift of $\simeq 2''$ in the optical image) i.e. four

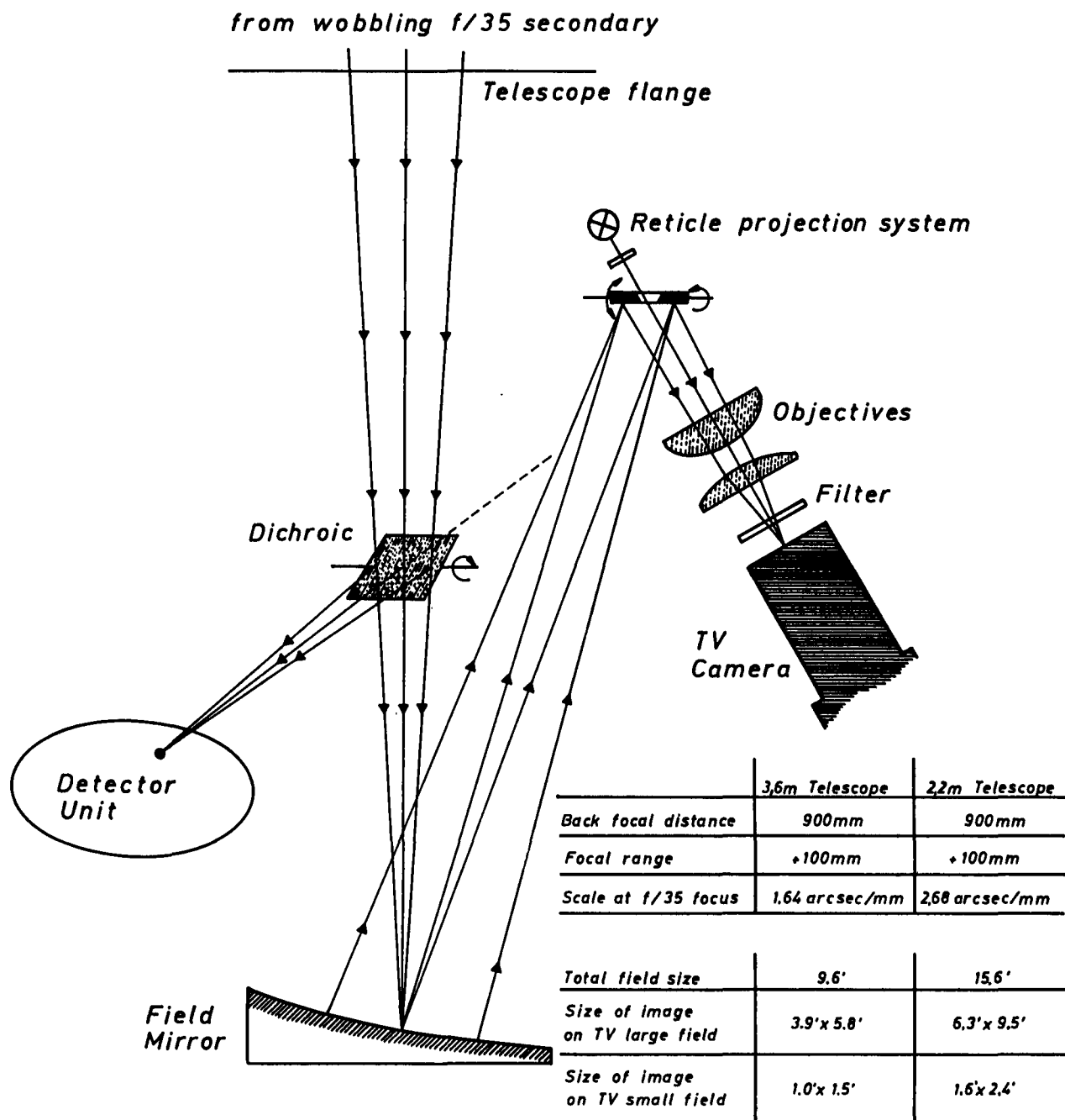


Figure 5.1: f/35 Photometer/Adapter

center positions in total.

If all operational modes are to be used (i.e. both detectors and acquisition with and without dichroics) then all four center positions must be stored. After selecting the required detector **DICHROIC IN/OUT** operates the appropriate mirror, and **GO TO CENTER** sets the guide probe on the correct center for the chosen combination. After centering an object, the guide probe can be moved either manually $\pm X$, $\pm Y$, **FAST/SLOW** or using the **SCAN GUIDESTAR** automatic mode to locate and center the cross on any suitable guide star in the field. The small field is normally used for guiding but it is often faster to use the large field initially when searching for a suitable star.

Note

*Do not forget before centering a new object to press the **GO TO CENTER** key.*

5.3 Commands

The photometer/adapters are controlled by the same F35 program. If CHOPR (3.6 m) or CHOP2 (2.2 m) appear in the center of the screen, press the **F/35** key first to activate this program.

The **F/35** softkey menus are shown in fig. 5.2. When more familiarity has been gained with the system, observers may find it more convenient to use typed commands instead of finding the appropriate softkey. Abbreviations are accepted by the software (e.g. FI, FIL, FILT). A list of command names can be obtained on the screen by typing ??. Commands which are usually typed are:

DI; D,I	:	dichroic in
DO; D,O; OU	:	dichroic out
LF	:	go to large field
SF	:	go to small field
BOLO	:	set bolometer detector
INSB	:	set InSb detector
FI,3	:	set TV filter 3

5.4 Operational guide

5.4.1 **F35 SET UP**

Generates the menu from which **InSb** or **Bolometer** must be selected as first step, (see 2.2 m) **DICHROIC IN/OUT**, **LARGE/SMALL FIELD**, **FILTER (TV)**. Note that the software automatically selects correct dichroic.

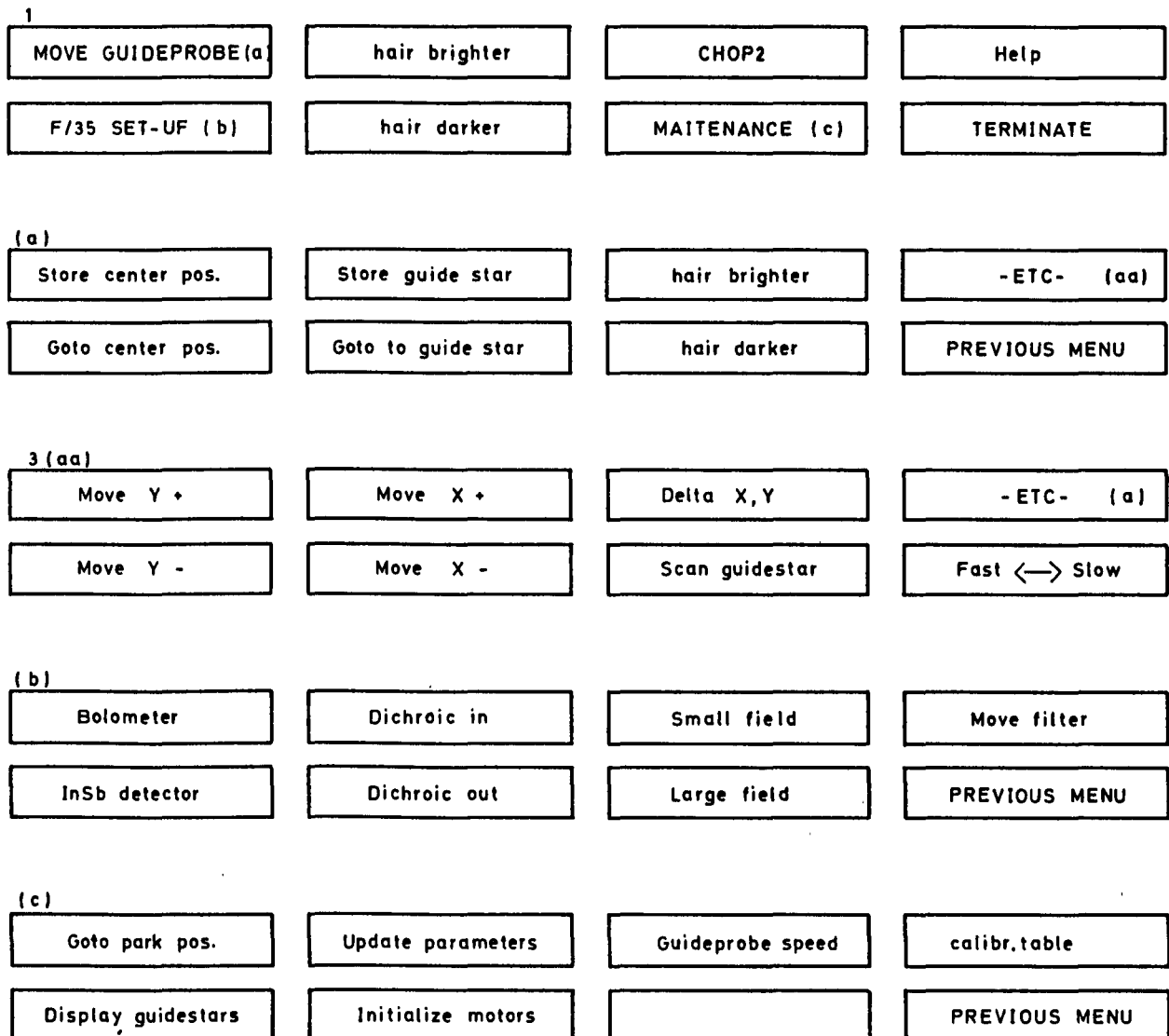


Figure 5.2: Photometer/Adapter softkeys (3.6 m and 2.2 m)

5.4.2 MOVE GUIDE PROBE

As stressed above, it is necessary to store one or more center positions for the guide probe before beginning observations. Normal procedure is to start with **DICHROIC IN**, acquire a bright star, peak it up in the IR beam (by stepping between half-power points using telescope offset mode and 0.5 steps), move guide probe so as to center the cross on the star and press **STORE CENTER**. Then press **DICHROIC OUT**, recenter the star by **MOVING GUIDE PROBE** and press **STORE CENTER**. If both detectors are being used this procedure must be repeated for each detector. The software automatically selects correct center position after **GO TO CENTER** according to the detector and status of the dichroic.

The guide probe can be moved by pressing the keys **MOVE ±** at **FAST/SLOW** speeds. These speeds can be changed in the form obtained by pressing **MAINTENANCE** followed by **GUIDE PROBE SPEED**. X, Y encoder readings are updated on the screen when the key is released. Small movements can be made by hitting the key twice rapidly. Note that the probe sometimes continues to move after the key is released but comes back to the position at the time of release.

Searching for guide stars can be performed as above or using the **SCAN GUIDESTAR** and **FAST/SLOW** keys. As long as the key remains pressed, the guide probe executes a rectangular raster over the field. Releasing the key stops the scan. The star can then be centered using the **± X** and **± Y** keys.

An offset in RA and/or DEC can be applied to the guide probe with the **Delta X, Y** softkey.

The guide probe position for any guide star can be stored by pressing **STORE GUIDESTAR** and entering a running number. This position can be recovered later by pressing **GO TO GUIDESTAR** and entering the same number. The list of stored guide stars can be displayed by pressing **DISPLAY GUIDESTAR** in the **MAINTENANCE** menu.

The illumination of the optical cross can be adjusted by pressing **X-hair brighter** or **X-hair darker**.

5.4.3 MAINTENANCE

This softkey generates a menu with commands to **DISPLAY GUIDESTARS**, set the **GUIDE PROBE SPEED**, and send the guide probe to **PARK POSITION**.

CALIBRATION TABLE sets the encoder values of the **PARK POSITION** and the ratio of arcsec to encoder values correspondence. This calibration should never be changed without prior consultation with the IR operations group.

UPDATE PARAMETERS generates a form to be filled in order to display, print or update the following parameters:

- The system installation parameters (such as telescope identifier, telescope scale, CAMAC LU, cartridge number for data files, detector program names (e.g. IRA), chopping mirror program names).
- The motor installation parameters (such as CAMAC station controller, CAMAC/NIM interface, cabling controller position, motors guide probe X, Y, TV filters wheel, dichroic mirrors, cross hair illumination, guide probe speed, position of the center of the TV filter 1, TV filter names).
- The four guide probe center positions.
- The scan parameters of the guide probe as given in **CALIBRATION TABLE**.
- The motors parameters (i.e. the encoder values of the offsets, and lower and upper limits).
- The catalogue of guide stars.

The parameters are entered by filling the form that appears on the screen. Fill the appropriate spaces using the “TAB” key to step the cursor and press “ENTER” to send the values to the computer.

If some problem occurs with the motors, it may be necessary to **INITIALISE** them.

Chapter 6

Detector units

Both detector units (InSb and Bolometer) are built into HD3 (L) dewars supplied by Infrared Laboratories and have identical optical and mechanical designs. Fig. 6.1 shows the optical paths and the location of the filter and diaphragm wheels.

The diaphragm wheel is in the $f/35$ focal plane. The filter wheel carries both the broad-band filters and CVF. Mirror M images the telescope secondary at the filter position. Both the filter and diaphragm wheels are connected via gears and shafts to DC motor/encoder units mounted externally on the dewar bottom covers. Positioning accuracy is 0.3° , which is about 1 encoder step.

The detector dewars are mounted on stands which can be removed and replaced without losing the optical alignment. Both dewars have ‘outer’ cryogenic containers filled with liquid N_2 which requires refilling by the observers (*in situ*) roughly every 6 hours.

For the InSb detector, the ‘inner’ container contains N_2 which is kept solid by pumping. This container requires refilling only every 8–10 days. This is done by the IR operators.

For the Bolometer, the ‘inner’ container holds liquid helium which is continuously pumped (~ 1 mbar) using a second, larger, pump permanently installed in the dome. This container requires refilling roughly every 24 hours (by removing from the photometer mount). This procedure lasts 2 hours, which must be taken into account for planning the observations.

Further details of the cryogenic handling procedures are given in the Technical and Maintenance Manual, but these operations are normally carried out by ESO staff on the mountain.

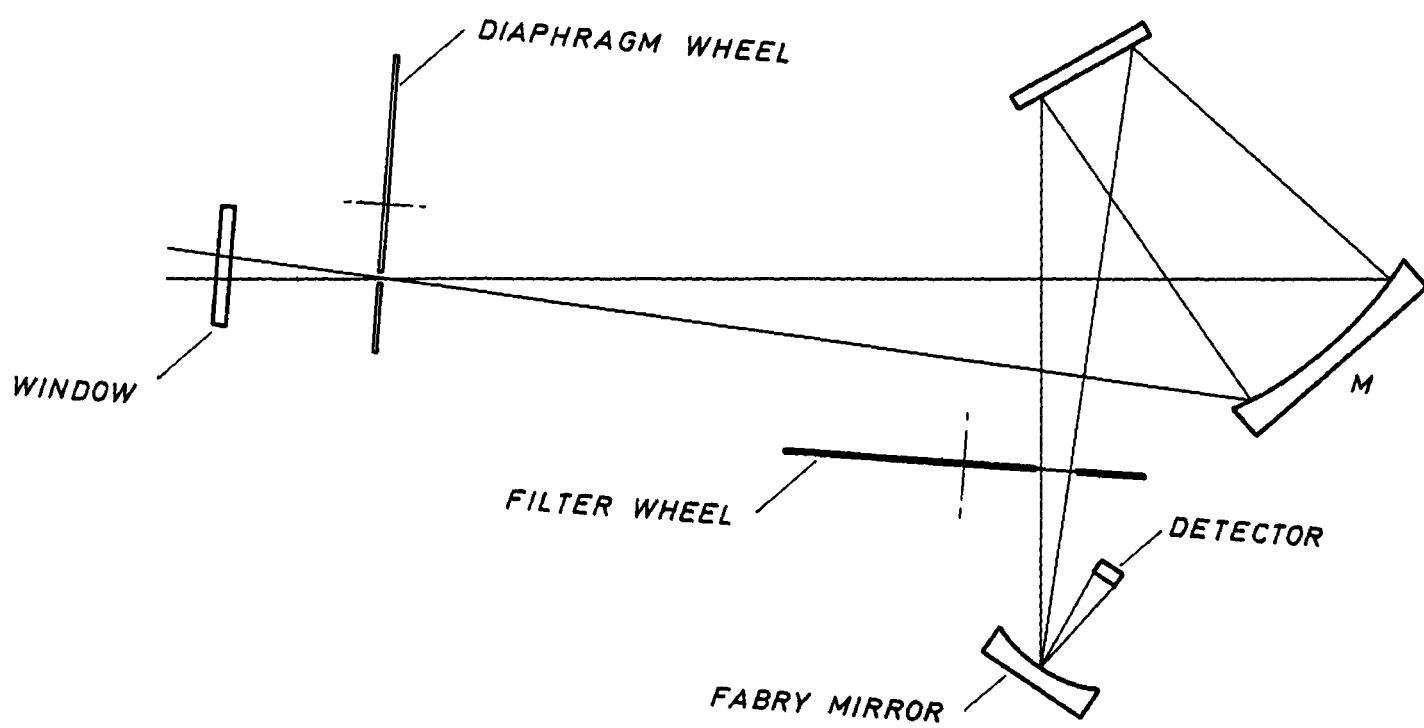


Figure 6.1: Schematic of IR photometer cold optics

6.1 Detectors and preamplifiers

6.1.1 InSb

The detector currently installed is an element (0.5×0.5 mm) from Cincinnati Electronics. It has a dynamic impedance of the order of $1000\text{ G}\Omega$ when pumped to solid nitrogen temperature (see Technical and Maintenance Manual). The feedback is via a 20 or 50 $\text{G}\Omega$ Eltec resistor which limits the frequency response to about 10 Hz. The system is linear to better than 2% provided that the output voltage does not exceed 500 mV peak to peak. (This is close to the saturation level for the PAR lock-in if no attenuator is used).

Depending on the background level, the observer must select via the computer terminal one of two fixed pre-amplifier gains determined by cold feedback resistors in the cryostat. Whenever possible, the higher gain should be chosen (command: `COMP,OFF` in IRA). This is the case for J, H, K photometry during night-time and for CVF observations at $\lambda \leq 3.5\text{ }\mu\text{m}$, but the exact wavelength depends on the diaphragm used. Otherwise, it is necessary to select the lower gain (`COMP,ON`) to avoid saturation by the background. For photometric measurements, the command `COMP,AUTO` automatically sets the high gain for the J, H, K bands and the low gain for L and M, and introduces a delay of 10 s whenever the gain is changed.

Warnings!

1. The optimum phase settings are different by 40° to 60° for the high and low gains.
2. The feedback resistors exhibit some voltage dependence, but the resulting non-linearity effects on the AC-signal are negligible because the maximum amplitude is limited by the saturation level of the PAR. *During sunrise and sunset, however, the usually low background levels at J, H, K, can be large and rapidly variable.* Under these conditions, photometry can become unreliable using the high gain setting, and it is advisable to use the low gain setting. The same recommendation applies for day-time observing.

Adjustment of the InSb preamplifier is explained in the Technical/Maintenance Manual. For normal operation the switch POWER should be ON and the BIAS OFF.

6.1.2 Bolometer

This is a 0.5×0.5 mm gallium doped germanium bolometer from Infrared Laboratories. At $p < 1$ mbar its dynamic impedance is $\simeq 1.5\text{ M}\Omega$ when shielded from radiation (e.g. with a blind filter or diaphragm in position). The preamplifier is also from Infrared Laboratories. For normal operation the POWER, BIAS and INPUT switches should all be ON.

Chapter 7

General operational guide

7.1 Signal chain

Fig. 7.1 shows the electronic signal chain. Separated coax lines are used for the signal and ground lines from the preamplifiers and are connected to the A and B inputs of the appropriate lock-in amplifier. Typing the required detector at the computer console automatically selects the correct signal chain. The required GAIN, TIME CONSTANT, DYNAMIC RESERVE, PHASE and OFFSET are set manually at the PAR lock-in amplifier. GAIN and DYNAMIC RESERVE are read by the computer and are printed out together with the data. Note that the observer has to select *only* the proper GAIN and PHASE (for COMP,OFF and COMP,ON; see later). The other parameters are set by the IR operators and should not be changed during the observing run.

7.2 Observational procedures

7.2.1 How to start the programs

- At the 1 m telescope: hit RETURN on the acquisition terminal, and answer IRA as username. The program will start, just answer the questions.
- At the 3.6 m and 2.2 m telescopes: hit RETURN on the f/35 (and CHOPR/CHOP2) terminal, and answer F35 as username. Read and follow the instructions displayed. The programs F35 and CHOPR (or CHOP2) will start and will activate the IRA program at the other terminal. Answer the questions.

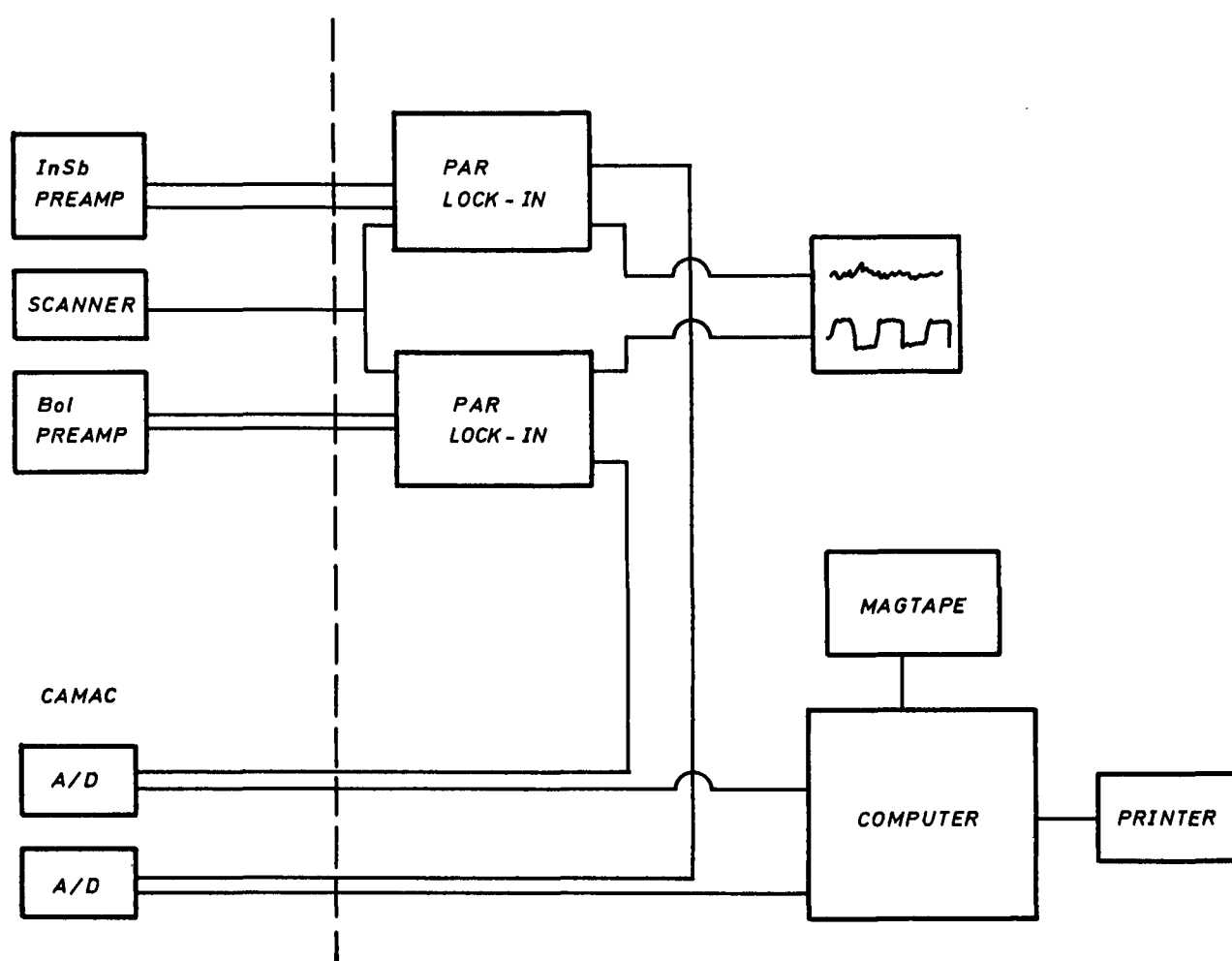


Figure 7.1: The electronic signal chain

7.2.2 How to start the observations

Basic operations required before beginning observation are:

1. Set or check parameters of the chopper.
2. Check that the correct detector has been selected (beam diverter mirror and software commands) and that the eyepiece mirrors at the 1 m are retracted.
3. Focus the telescope.
4. Mark IR beam position. This is normally done by peaking up the IR signal on a bright star and marking the position of the optical image on the TV screen at the 3.6 m and 2.2 m telescopes, and by adjusting the cross hair of the eyepiece at the 1 m.

To center an object with the signal, the observer should always use the so-called “half-power points method”:

- set the offset of the telescope to 1" (1 m) or to 0.5" (3.6 m and 2.2 m).
 - move star out of the diaphragm in one direction.
 - cross back through the diaphragm by stepping with offsets.
 - starting around half maximum signal, count the number of offsets necessary to pass the maximum and to return to half maximum signal.
 - move star back half the number of offsets.
5. Check that the signal is correctly phased (on PAR) using a bright star. The positive beam should be defined so that a movement of the telescope east by an amount equal to the chopper throw gives a negative signal of the same amplitude (not zero).
 6. With the InSb detector it is necessary to decide whether or not to apply background compensation in case COMP, AU has not been selected. Remember that using compensation implies a phase change (PAR).
 7. At least at the beginning of a run, one of the stars in the standard star table must be measured in ZP (zero-point) mode if on-line magnitudes are required. (See 8.6.2).
 8. When observing, particularly if long integrations are involved, it is useful to acquire an offset star in order to monitor and correct the tracking. This can be achieved with the off-axis guiding mirror at the 1 m or with the guide probe at the 2.2 m and 3.6 m telescopes.
 9. The handset can be used for guiding continuously during a measurement. However, one should note that the guide buttons are automatically disabled when the telescope beam switches and during the settling DELAY time selected.

Warning

NEVER work at the TCS terminal while IRA is INTEGRATING. This would result in a crash of the full system (e.g. do not enter coordinates during the measurement of an object).

Chapter 8

The IRA acquisition program

8.1 Introduction

The Infra-Red Acquisition program (IRA) is used to:

- Set the filter and diaphragm wheels.
- Control the telescope beam switching.
- Set the parameters and handle the data acquisition.
- Record in either of three modes: photometry, spectroscopy and scanning.

The IRA program will be called automatically when starting the F35 program at the 3.6 m and 2.2 m. At the 1 m log in under IRA.

The HP softkeys are used for mode selection and for starting and stopping the data collection. An alphabetical list of available commands can be printed by typing `HELP`. The software and data output used with the three photometers are similar. Below we give some definitions of the quantities desired and displayed by the software which should prove useful in the analysis of the data.

8.1.1 Counts

The integer numbers shown on the screen immediately after each integration, usually referred to as “counts”, are derived from the analog output of the PAR phase sensitive amplifier using a 12 bit analog to digital converter which produces an output of ± 2048 for an input of ± 2.56 volts. As the nominal full-scale analog output of the PAR is ± 1 V, this should result in ± 800 units. Since the basic integration time (IT) is 10 ms and the counts are normalized to 1 sec the numbers shown are a hundred times larger, and we would thus expect ± 80000 “counts” for plus or minus full-scale on the PAR. In practice, this number turns out to be

approximately 83500 (4.4% larger). For integration times (IT) longer than 1 s the average counts s^{-1} (c_i) are shown and a standard deviation is calculated as:

$$T = \sqrt{\frac{\sum c_i^2 - \frac{(\sum c_i)^2}{IT}}{IT - 1}}$$

which is shown directly under the observed counts. Note that the standard deviation *will not* decrease with increasing integration time.

8.1.2 Beam switched photometry

Photometry always starts with the positive beam on the source (giving a measurement called “A”) followed by a measurement in the negative beam (called “B”). An ABBA sequence is called a “cycle” and consists of 2 AB “pairs”. The average of the differences (A–B) of all observed A–B pairs is shown on the output as “AVE”, which is then multiplied by the sensitivity setting on the PAR (in volts \equiv GAIN) to give the intensity “INT”.

8.1.3 Error calculations

We adopt the following nomenclature:

- IT : observing time per individual (A or B) measurement.
- n : number of AB pairs.
- A_i, B_i : measurement ($i = 1, \dots, n$).
- a_i, b_i : errors of an individual measurement pair (A_i, B_i).

Then,

$$AVE = \frac{\sum (A_i - B_i)}{n}$$

Two errors related to this average are calculated, called E1 and E2. E1 is the quadratic average of the individual errors,

$$E1 = \sqrt{\frac{\sum a_i^2 + \sum b_i^2}{n}}$$

and E2 is the standard deviation of the distribution of the (A–B) differences,

$$E2 = \sqrt{\frac{\sum [(A_i - B_i) - AVE]^2}{n(n - 1)}}$$

In addition, two relative errors are derived from E1 and E2, called %E1 and %E2.

$$\%E1 = \frac{100 \times E1}{\sqrt{n} \times AVE} \quad \text{and} \quad \%E2 = \frac{100 \times E2}{\sqrt{n} \times AVE}$$

Expressed in magnitudes these errors are $\Delta m = -2.5 \log(1 - \frac{\%E}{100})$, where %E represents the largest of %E1 and %E2.

Note

Note that E1 and E2 do not improve with an increasing number of cycles with a given integration time, whereas %E1 and %E2 do.

Under ideal observing conditions, E1 and E2 should be equal. However, in real situations they are not, because E1 is *not* sensitive to slow effects like seeing and clouds, while E2 is. Note that E2 does not mean much when only few cycles are averaged.

Therefore, if the baseline shows curvature or if, due to bad seeing or centering, signal variations occur in excess of the sky/detector noise, then E2 will be larger than E1. In this case, the measurement should be judged less reliable. In any case, both E1 and E2 are internal errors and a *real estimate* of the observational accuracy, including systematic errors, can only be obtained from repeated observations. Note that internal errors of less than one percent are almost always dominated by larger extended errors. To achieve 1 percent accuracy in the final reduced data requires great care.

Finally, the noise figure is defined as $NF = 1.2 \times E1 \times \sqrt{IT} \times GAIN$. The noise figure is used in the mapping mode to set the level above which a source will be detected (see section 8.10.1).

8.2 Information tables

The following tables can be displayed and printed for both InSb (IN) and Bolometer (BO):

- TA : filters, CVFs and diaphragms
- ST : standard stars
- ZP : photometry zero-points as function of
wavelength and diaphragm
- NF : noise figures for SEARCH mode.

The commands to display these tables are:

```
INFO,IN,ST,'string'  
      BO,ZP,  
        ,NF,  
        ,TA,
```

Where 'string' can be any character string that is used as a flag to enable printing the table and saving it on the magtape.

8.3 Detector selection

The required detector is selected by typing INSB or BOLD

This enables the computer to access the correct parameter tables, to control the appropriate filter and diaphragm wheels and to select the correct signal chain.

8.4 Mode selection softkeys

The possible observing modes are displayed in the upper area of the observer's console. They are **PHOTOMETRY**, **F-PHOTOMETRY**, **SPECTROMETRY**, **F-SPECTROMETRY** and **SCANNING** (Mapping). To select one of these modes simply press the corresponding softkey. This will result in a display of the parameters currently set in that mode. At the same time, the softkey functions are changed to **START**, **STOP**, etc., as required to control the data acquisition. It is possible to revert to mode selection by pressing **MENU**.

8.5 General commands

COMMENT,XXXX	: displays, prints and writes any comment on magtape.
COMP,ON	: lowers the gain of InSb detector (c.f. 6.1.1). Must be used for L and M.
COMP,OFF	: sets gain of InSb to high. Use for J, H, and K.
COORD	: displays, prints and writes the telescope coordinates on magtape.
MAGTAPE,ON	: (default).
MAGTAPE,OFF	
PRINTER,ON	: (default).
PRINTER,OFF	
INIT	: to restart the program.
THRO,AMP,DIRECTION,FREQ	: <i>at the 1 m, records but does not set</i> the sky chopping parameters (throw), e.g. THRO,15,0,20 means that the amplitude is 15 arcsec in direction 0 (α) and the frequency is 20 Hz.
THRO	: reads the sky chopping parameters (see above) set by the programs CHOP2 at the 2.2m and CHOPR at the 3.6 m.
TIME,CH,YEAR,DAY,HH,MM,SS	: changes the computer time.
TIME,UT	: sets Universal Time for output.
TIME,ST	: sets Sidereal Time for output.
TIME	: checks time.
SUSP	: suspends the program; to resume type GO,IRA,1 from RTE.

8.6 Photometry

In this mode the telescope is moved automatically to provide beam switching in the sequence ABBA. The observer must ensure that the signal is positive in the A beam and negative in the B beam (section 7.2).

Integration time at each telescope position is ITIME (IT) seconds and one ABBA sequence constitutes one CYCLE. A delay (in seconds) is introduced after each telescope movement and a PAUSE (in seconds) after each filter movement before integration starts (this command is particularly important for CVFs, section 8.7.1).

8.6.1 Commands

The available commands are:

INSB or BOLO : to select detector
 PHOTOMETRY : Softkey, selects mode
 FISE : stores sequence of required filters (e.g. FISE, J, H, K, L, M). Filter names must correspond to those in the tables.
 FILT : sets required filter (e.g. FILT, K)
 DIAP : sets required diaphragm (e.g. DIAP, D4). Diaphragm names must correspond to those in the table. For FISE, FILT, and DIAP commands, *encoder values and code names are equally accepted.*

If message ‘‘Setting failed. Try manual’’ appears, repeat the command. If this does not work, move the filter wheel a hundred or so encoder values from the required position, and repeat the commands. If problem persists call the IR operator.

ITIM : sets required integration time in integer seconds (e.g. ITIM, S)
 CYCL, LCYC, MCYC, %LIMIT : specifies minimum and maximum number of cycles acceptable and the desired r.m.s. accuracy on the mean level, e.g. CYCL, 2, 20, 1, means that integration will extend over at least 2 cycles and will stop when accuracy reaches 1% or when number of cycles reaches 20. The accuracy is given by max (%E1, %E2). The CYCL command is enabled by:
 LIMI, ON : sets limits of cycles according to CYCL command.
 LIMI, OFF : disables the automatic stop. The integrations will continue until you press the STOP command.
 LIMI, RE : sets the REPEAT mode; the program will measure repeatedly one independent cycle in the same filter until you press the STOP key.

OFFSET,ALPHA,DELTA : sets the telescope offset for beam switching. e.g. **OFFS,15,0** the telescope will beamswitch 15 arcsec in R.A., 0 in DEC.
DELAY,# : sets delay in seconds after telescope movement e.g. **DELAY,3** after the telescope offset, the program will wait for 3 sec before starting measurement.
PAUSE,# : sets delay in seconds after filter movement. e.g. **PAUSE,4** . Once new filter is set, the program will wait for 4 sec before starting the measurement.
IDENTIFIER, : enter any text to identify measurement. e.g. **IDENT,SECRET GALAXY 1**. *this command must be entered before measurement can start.*

Pressing **START** will position the first filter listed under FISE.

Do not enter any commands until filter is set or message setting failed appears. In the latter case, press **START** again. Once filter is set you can check signal optimization, settings on PAR, pointing, etc. When satisfied, pressing **START** again will initiate measurement which will normally proceed until the specified %LIMIT or MAX number of CYCLES is reached. At this point the next filter specified in FISE will be positioned and the procedure is repeated.

Measurement can be stopped *at the end of the current CYCLE* by pressing **STOP** and at any time with **ABORT**. After an **ABORT** the telescope always goes back to the positive beam. Note that the current measurement will not be saved after an **ABORT**. To restart after **STOP** or **ABORT** press **START**.

The commands **REPEAT**, **PREVIOUS**, **NEXT**, **PREVIOUS,n** and **NEXT,n** are used to repeat the measurement in the current filter, to go back n or advance n filters in FISE. If you notice that a parameter such as the gain is wrongly set, press **STOP** then **REPEAT FILTER** after changing the setting. If you do not want to continue press **STOP** then **NEXT FILTER**.

END terminates measurements. New **IDENTIFIER** required before re-starting.

8.6.2 Zero point measurements

If on-line magnitudes are required it is necessary to have measured one of the stars listed in the ST table in the "Zero point mode" using the same diaphragm and filters. Use the command,

ZPME,IDENT (e.g. **ZPME,HR5128**)

The telescope will move automatically to the requested star. Measure as for PHOTOMETRY. No **IDENT** required.

Zero points are stored in a table which contains locations for all the possible filter-diaphragm combinations. After a ZP measurement the command

ZPOI,DI

displays the old and new zero points for the diaphragm used. The commands,

ZPOI,SA or,
ZPOI,SA,Filter

can be used to replace all or some of the old zero points by the new ones. To change or introduce any zero points, the command ZPOI,CH,Diap,Filt,zp can be used e.g.
ZPOI,CH,D3,J,7.564.

8.6.3 Standard star measurements

When measuring a standard star, the program will compute and display the differences between observed magnitudes and the standard values.

The telescope can be pointed to any of the standard stars in the table by the command,

STDP,IDENT... (e.g. STDP,HR 5128).

Measure as for PHOTOMETRY. No IDENT required.

After commands ZPME and STDP, the first START is omitted. Pressing START will then actually start the measurement.

8.6.4 Photometry data output and on-line reduction

All the relevant parameters mentioned already appear on the printer and magtape. Also appearing are:

TELESCOPE COORDINATES (after each IDENTIFIER)
TIME (after each cycle)
AIRMASS (after each cycle)

The measurements are printed in rows of 8 numbers or two cycles of ABBA. Individual 10 ms integrations are summed within each 1 sec period and the numbers printed are the averages over IT of the 1 sec sums. The standard deviation calculated from the 1 sec sums is printed below each measurement. The data printed comprise:

- AVE - the mean value of A-B
- INT - AVE \times PAR sensitivity
- E2 - standard deviation of sample of A-B values
- %E2 - standard deviation of mean A-B as percentage of mean
- E1 - combined standard deviations of individual A and B measurements
- %E1 - E1 expressed as standard deviation on mean as percentage of mean.
- MAG - Magnitude and error calculated using measured ZP and including airmass correction according to extinction values in ST tables. The extinction values can be entered by the observer typing: EXTI,IN: (not yet implemented).

8.7 CVF Spectrophotometry

8.7.1 Setting of CVFs

Operation in this mode is almost identical to PHOTOMETRY. The CVFs are controlled using the command,

LCVF,CVF#, λ_{min} , λ_{max} ,step

e.g. LCVF,2,2.6,3.0,15 means that CVF2 will move automatically and stop at 15 equally spaced positions between 2.6μ and 3.0μ . Pressing START moves the CVF to the starting wavelength. A second START will initiate the automatic sequence. The time spent at each position is determined by the requested IT,CYCL,DELAY and PAUSE as in photometry. *Do not forget to take into account the atmospheric transmission when setting your CVFs.* Fig. 8.1 shows typical standard star measurements for the four CVF ranges.

The CVFs can also be set using the command:

CCVF,CVF#, $\lambda_{central}$,width,step

It is possible alternatively to control the CVFs using encoder positions directly with the command:

CVF,encoder min.,encoder max.,step

e.g. CVF,200,300,5 means that the filter wheel will step between encoder, positions 200 and 300 in intervals of 5 encoder steps. It is also possible to set discrete positions of the CVF, unequally spaced with CVSE,ENC1,ENC2,... (up to 11 positions may be given). To get the equivalence between encoder values and wavelength, type:

WAVE,WE, λ	:	to get the encoder value corresponding to λ .
WAVE,EW,n	:	to get the wavelength corresponding to encoder value n.
WAVE,CV,#,1	:	to list all encoders and wavelengths of CVF #.

Resolving power $\lambda/\Delta\lambda$ is about 70 for all CVFs and one resolution element in wavelength corresponds to about 6 encoder steps.

The InSb detector is relatively insensitive to movements of the filter wheel. With the Bolometer, however, a **PAUSE** of at least 5 sec is advisable (section 8.6.1).

8.7.2 Measurement

Before starting a CVF measurement set GAIN of the PAR and scale the display: choose a filter in order to get approximately the maximum signal. For example,

WAVE,1.65	:	will give you encoder value 760 for 1.65 μ .
FILT,760	:	will position filter to 1.65 μ

Then adjust the GAIN of the PAR and estimate the number N of maximum 'counts' that you will get. (Remember that the program will display the counts and *not* the intensity).

Then scale the display with the command:

SCALE,Y,MC,0,2N	:	to scale the Y-axis (counts) between 0 and 2N (MC meaning "Mean counts", to distinguish from fast spectrophotometry). The scaling in X (wavelength) is done automatically.
-----------------	---	--

Before starting the measurement, initialize the display with,

GRAP,CU	:	(i.e. Graph current).
---------	---	-----------------------

At the end of a "scan" (the complete CVF spectrum), you have the possibility to repeat it, typing: **AGAIN**. The following scan will be displayed (and plotted later) with a different symbol. There are 6 different symbols and several possibilities for plotting your results. Commands are:

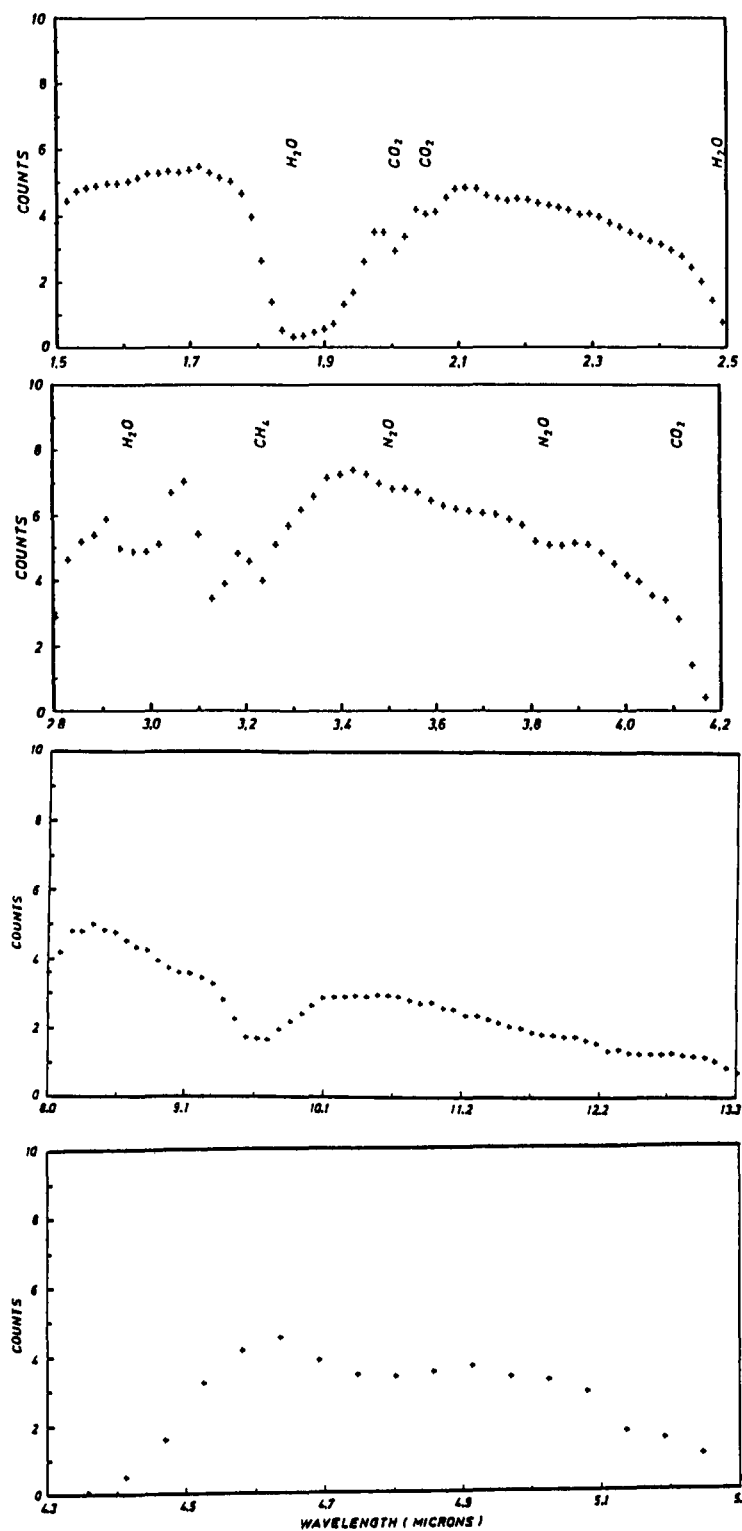


Figure 8.1: Typical standard star spectra for the four CWFs

PLOT,LS	: to plot after each scan the <i>last</i> spectrum with the corresponding frame
PLOT,FR	: to plot only the frame (identifier; λ_{max} , λ_{min} , step; number of cycles, etc).
PLOT	: to plot after each scan the obtained spectrum without frame
PLOT,AV	: to plot the average (in case of more than one scan) of the signal for each point with the corresponding errorbar.

8.7.3 Standard star measurements

The measurements of standard stars for CVF spectrophotometry must be done exactly in the same way (**same setting and same night!**) as your program objects.

For the InSb range, choose standard stars which are *really* CVF standards (usually G dwarfs). Otherwise, you may run into big trouble when reducing your data. Thus, *standard star measurements may take longer than those of your objects* (especially at the 1 m), but there is no way to avoid it!

For the bolometer range, (8–13 μ), you may choose as standard star any (10 μ) bright star whose spectrum is known to be featureless in that range.

The determination of atmospheric extinction in the near infrared is a complicated problem because the absorption is due mainly to molecular bands, many of which saturate at very low absorber concentrations. Thus, **the absorption over a narrow bandpass is not a linear function of the airmass**. Strictly speaking it is not a simple function of any sort, but depends on curve-of-growth effects for overlapping lines of widely differing strengths (see Manduca and Bell, 1979, *P.A.S.P.*, 91, 848).

The best way to correct for atmospheric extinction would be to compute the theoretical atmospheric transmission for the La Silla atmosphere and the set of filters employed. This is not yet available. Experience shows, however, that measuring nearby standard stars (airmass *and* region of the sky) gives acceptable results, at least in the “good” atmospheric windows.

The observer must be well aware of this problem and *must be very careful when choosing a standard star for CVF*. It is recommended to read Le Bertre, 1988 (The Messenger No. 53, p. 55) to convince oneself of the difficulty of spectroscopy and spectrophotometry in the 3.0–3.5 μ range.

8.7.4 On-line reductions

Not yet available.

8.8 Fast photometry

Not yet available as standard package in IRA.

8.9 Fast spectrophotometry

Not yet available.

8.10 Scanning (mapping)

It may be necessary to make a small and quick map around a center position to search for a source. In that case, the program can make a spiral (and displays it). The command is, `SPIR,STEP,IT [NFT]`, where `STEP` is the step of each increment, `IT` is the time of each step and `NFT` is the noise figure time measurement at the center.

The first `STOP` interrupts the scan at any point and second `STOP` aborts the scan at that position.

More generally, the scanning mode allows step by step mapping of rectangular fields. There is of course no beam-switching. If search mode is used (see section 8.10.1) the `THROW` selected must be a multiple of the `OFFSET`.

Mode is selected by pressing `SCANNING`.

Parameters of the field to be scanned are set using the command:

`SFIELD, α , δ , $\Delta\alpha$, $\Delta\delta$ (e.g. SFIELD,60,50,6,10).`

This map will cover a region 60 arcsec in R.A. by 50 arcsec in DEC in steps of 6 arcsec along lines of R.A. separated by 10 arcsec in DEC.

Other useful commands are:

`IT` : integration time per point

To initiate the map:

1. enter `IDENT`
2. move telescope to required `FIELD CENTER`
3. press `STAR`
4. move telescope to any desired reference position (which can also be the `FIELD CENTER`)

5. press **START**

The telescope will now move to the NW corner of the map and begin the scan.

The command **BREAK** stops the scan at any point. It is possible in **BREAK** to change to another mode (e.g. **PHOTOMETRY**) and then return to the map. **GO,BREAK** returns telescope to coordinates of **BREAK** point.

FIELD CENTER returns to center of the scan. **REFERENCE** goes to the reference position. Once at the **REFERENCE** position it is possible to correct the telescope coordinates with the command **CC**.

8.10.1 Search mode

This is used if an indication and coordinate printout are required for any signal registered above a given threshold, by the command:

DISCRI,m

where m is an integer. The detection threshold is $m \times NF$ (c.f. 8.1.1). The command for setting this mode is:

SEARCH,ON

Remember that the chopper **THROW** must be a multiple of the **OFFSET** because **SEARCH** looks for the correction sign change as the source moves from the positive to the negative beam. The noise figure (**NF**) used by **SEARCH** must first be measured in the **PHOTOMETRY** mode for the appropriate filter and diaphragm using the command:

NFME,FILT (e.g. **NFME,K**)

Sources detected during the scan can be listed at the end using the command:

SOURCE,LI

The telescope can be directed to any source in the list using the command:

SOURCE,#

8.10.2 Data output in scanning mode

IDENT, COORDINATES OF MAP CENTER AND REFERENCE, IT, FILTER, DIAPHRAGM, GAIN, DR, THROW, OFFSET, SFIELD and AIRMASS are printed at the beginning of the map. Measurements and standard deviations are printed in rows of up to 8 points as in photometry. A new line is started for each line of the map. Because the telescope always starts each line at W edge of a map, the corresponding points in the lines correspond to the same R.A. values. Time and coordinates corresponding to the beginning and end of each scan line are printed after each line. Any sources detected in SEARCH mode are listed at the end of each scan line with IRS number and coordinates.

Chapter 9

Termination

At the end of an observing session:

1. Type **TERM** on the terminal used to request the detector program (e.g. IRA). This puts an end-of-file mark on the magtape.
2. At the 2.2 m and 3.6 m, press TERMINATE twice on the terminal used to control CHOP2 or CHOPR, and F/35.
3. Fill OUTER cans with N₂, if necessary.
4. Fill in the night-operations report and deposit it in the red box at the hotel entrance.
5. Take out your magtape and deposit it in the tape mailbox.
6. Go to sleep!

Chapter 10

Troubleshooting

1. No response to softkeys. Terminal is probably blocked. Press RESET twice and “RETURN”.
2. Garbage on terminal. Press “RESET” twice and “RETURN”, or type FRAME to clean the console.
3. Problems with motor positioning or encoder readings. Press the INITIALIZE key under IRA, CHOPR/CHOP2, or F/35 as appropriate. If problem remains, type INIT to restart the program.
4. No signal when object centered. Check that the mirrors and/or dichroic are in proper position. At the 2.2 m and 3.6 m check that GUIDE PROBE is at CENTER POSITION.
5. Commands not accepted. It may be a time-out in IRA; repeat the command. At the 2.2 m and 3.6 m check that correct program CHOP2/CHOPR or F/35 is active.
6. Problems with CHOP2 commands. Go to MAINTENANCE menu and press RESTART and RESTORE or CHECK AIR GAPS.
7. Overshoot in the modulated square wave and/or amplitude unstable: stop chopper and start again. The amplitude is probably too large.
8. Losses of phase synchronization (red light on at the right side of the PAR). Call the IR operator!
9. Irregular behaviour of the detector (e.g. sudden loss of sensitivity; increase of noise, etc.). Check noise at the PAR with diaphragm and filter blind positions. Noise should be $\simeq 25 \mu\text{V Hz}^{-1/2}$ with InSb (COMP, OFF) and $\simeq 80 \mu\text{V Hz}^{-1/2}$ with Bolometer. If not, **call IR operator**. If noise is OK, check clouds and/or humidity.
10. No signal (and no noise) at L and M with InSb. Detector is probably saturated. Check that COMP is ON.

11. Drift of the signal in the thermal bands. Adjust offset of chopping.
12. The signal in L or M increases suddenly and gets in “OVERLOAD” (negative or positive), the telescope is looking at a part of the dome. (*Very sensitive at the 2.2 m telescope*). Move dome.

If the problem remains, call the IR operations group (24h/24 bip 28).

Appendix A

Available filters and diaphragms

Table A.1: Filters and CVFs (InSb and Bolometer)

InSbs			Bolometers		
Name	$\lambda_c(\text{mm})$	$\Delta\lambda(\text{mm})$	Name	$\lambda_c(\text{mm})$	$\Delta\lambda(\text{mm})$
J	1.24	0.2	K	2.18	0.5
H	1.63	0.3	L	3.78	0.7
K	2.19	0.4	M	4.66	0.5
L	3.78	0.7	N	10.36	5.2
M	4.66	0.5	N1	8.36	0.85
			N2	9.67	1.65
K0	2.24	0.5	N3	12.89	3.7
LA	3.64	0.9	Q0	18.56	5.6
			Q1	>19.7	
			Q2	>23	
CVFs			CVF		
CVF 1	1.5 – 2.5 μm		CVF 18	18 – 14 μm	
CVF 2	2.5 – 4.5 μm				
CVF 3	4.1 – 5.5 μm				

Note

For latest updated listing use computer display (see 8.2).

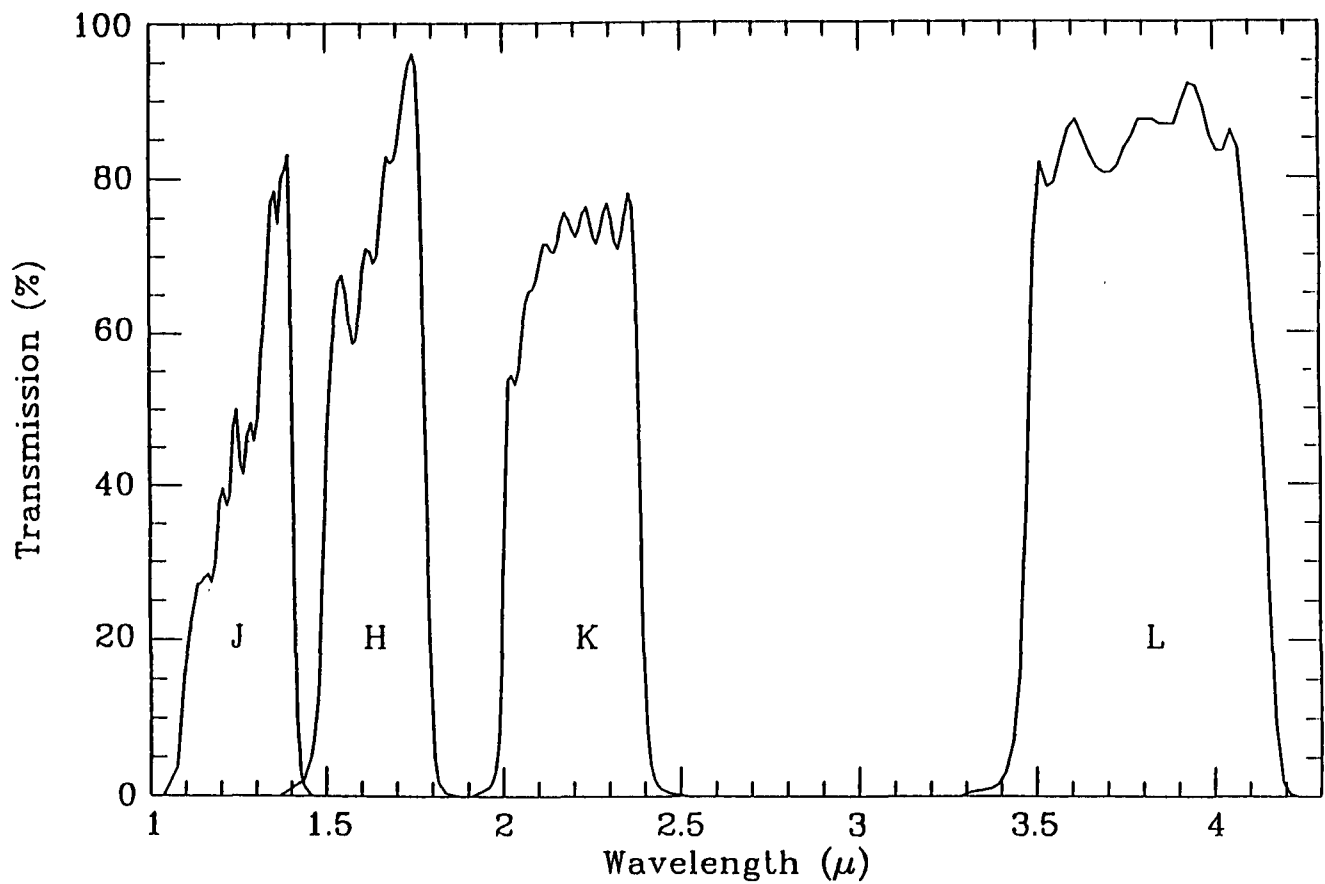


Figure A.1: Transmission curves of the J, H, K, L filters. These curves have been obtained under operating conditions and represent the actual transmissions of the filters and detector.

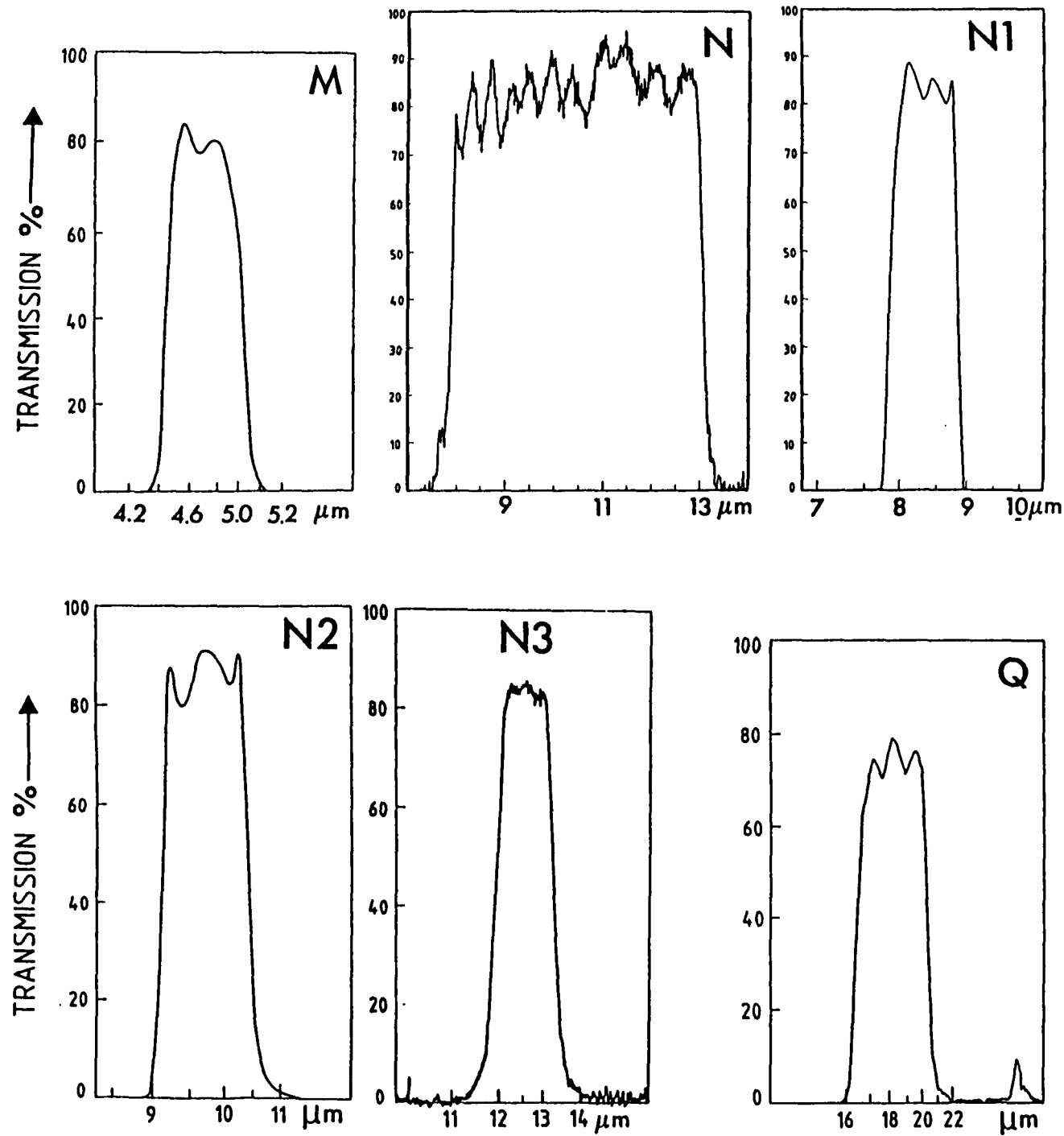


Figure A.2: Transmission curves of the M, N, N1, N2, N3, Q0 filters. The response of the detector is not considered in these curves.

Table A.2: Circular diaphragms (InSb and Bolometer)

NAME	DIAMETER			
	mm	Arcsec		
		3.60 m	2.2 m	1 m
D1	6	10	16	30
D2	4.5	7.5	12	22.8
D3	3.0	5	8	15.2
D4	2	3.3	5.4	10
D5	1	1.65	2.7	5

Warning: The values given for the diaphragms are nominal. The actual sizes depend on the beam profiles of each detector. If important for your observations, *measure their real sizes before starting observations* by stepping across a bright star on α and in δ with 1'' steps.

Appendix B

Limiting magnitudes

The following magnitude limits have been obtained during tests and can be used as a guide. Of course, the actual limits will depend on observing conditions, particularly in the poor atmospheric windows for CVF spectrophotometry where humidity and sky emission may play a major role.

Warnings!

1. The wavelength dependence of the sensitivity gain is determined by the relative contributions of the noise from the detector (dominant at J,H), the telescope thermal emission (L,N), and the thermal sky emission (M,Q).
2. The performances in J,H,K are proportional to the area of the telescope mirror while at longer wavelengths (as they are set by background photon noise) they are proportional to the mirror diameter and diaphragm size.
3. Day time limits are degraded by at least 3 mag in J,H,K.
4. Objects must be at least $\simeq 6$ magnitudes brighter than the above limits in order to show a signal visible on the chart recorder and the PAR.

Table B.1: Limiting magnitude and sky brightness (1σ in 30 min integration time)

Band	3.6 m (D = 7".5)	2.2 m (D = 8")	1 m (D = 15")	Sky (mag arcsec ⁻²)
J	20.6	19.8	17.4	16
H	19.8	19.3	16.9	14
K	19.0	18.4	15.9	12
L	14.7	13.8	11.9	3
M	11.7	11.0	9.1	0
N	8.8	7.4	6.2	
Q	4.5	3.5	2.4	

Limiting magnitudes for CVFs are about 3 mag lower in the corresponding bands.

The following limits correspond to the brighter magnitudes which can be measured **without compensation** (see 6.1.1).

Table B.2: Saturation limits

Band	3.6 m	2.2 m	1 m
J	5.1	4.3	2.0
H	4.6	3.5	1.3
K	4.3	3.2	1.1