GODOT

Version 2.0
Control and data recording program for the SAAO CCD system

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Contents

1 Introduction

The program runs in an IBM PC-AT computer equipped with a 110 Mbyte hard disk, a monochrome monitor, an extended keyboard and an 80-column printer. The main box houses an interface board for receiving external 1 kHz interrupts and serial time data, a 1 Mbyte memory board which is used as the primary image store, a magnetic tape interface, a CCD interface and a frame-grabber. A 9-track magnetic tape drive is connected by two flat cables to the relevant interface board, and this is capable of writing and reading 1600 and 800 bits/inch(bpi) tapes which constitute the means by which data are taken away from the telescope.

The CCD interface allows commands to be sent to the CCD controller on the telescope, receives telemetry relating to the state of the CCD camera, filter box, and acquisition head, and mediates the flow of data from the CCD. The CCD controller is based on a Transputer which is mounted in a box attached to the cryostat. The Transputer generates all the waveforms necessary for reading out the CCD, and transmits data via optical fibres to the CCD interface in the IBM.

The frame-grabber is used to display images on a colour monitor.

16-bit data (giving a range of 1 to 32767 counts) flow from the CCD to the 1 Mbyte memory and are processed through a look-up table (LUT) to give 8-bit data which are transferred to the frame-grabber for display. The frame- grabber has its own set of LUTs which allow further manipulation of the displayed image. It also has a hardware cursor which may be moved under program control to mark or select any part of the image.

Both the frame-grabber buffer and the 1 Mbyte memory are volatile, ie data they contain are lost if there is an interruption to the power supply or if there is a program crash. Data are not safe until stored on the hard disk and/or on the magnetic tape. Storage of data is not mandatory and , eg, test images may be discarded when overwritten by a subsequent image.

Data are stored on tape in FITS format, and the FITS header is stored with the data in a disk file as well as in the 1 Mbyte data store so that details of the exposure are always available with the data wherever they reside.

The program is written in C and compiled with the Microsoft version 4.0 C Compiler.

2 Startup

To start the program, type C and press Enter. If there is no sensible response, type in GODOT (upper or lower case or a mixture) and press Enter. This initiates a several-stage process, which will take a little longer the first time you use the program. During this startup phase you log on to your own personal directory and supply details of the observing setup, and various equipment checks are carried out by the program.

Several files are saved on the disk with information about the CCD in use, the kind of filter box and the names of the filters, the coordinates of objects in your program, and what images are stored on tape and on the disk. You only have to enter this information once and on subsequent startups the program reads in the data from the disk files. The files are best kept together in a directory, which is conveniently referred to by your initials. Be sure to use the same initials each night as otherwise the program will not be able to find the information you have entered - and in particular you will be considered to be a new user and the image files previously stored may be overwritten.

The hardware is complex and there are numerous pieces which may or may not be present or working properly, so the program spends a little time at the beginning checking the status of the interface boards. It is possible to work with a reduced complement of features, but generally the following should be present:

- CCD interface.
- Frame-grabber.
- 1 Mbyte memory at address segment 0x10000.
- Magnetic tape interface.
- Mag tape drive unit.
- External 1 kHz interrupts from the time service.

The program checks the communications with the **Transputer** in the controller on the telescope. If it cannot make contact, an error message appears on the screen. At this stage you should go outside and check that power is being supplied to the controller. If not, switch on the power supply in the white box attached to the base of the telescope. In any case, then press the **red RESET** button on the controller. The program will also prompt you to do this if necessary.

The program now collects information about the CCD chip in use, and about what filters are installed. The information you supply is stored and automatically read on subsequent startups. If you change filters during the run you will have an opportunity to change the names in the setup file once the program proper has started.

If South African Standard time (SAST) and Sidereal time are not being supplied in serial form from the time service you will be prompted for a starting time, otherwise the program automatically picks up the correct time. The external 1 kHz interrupts from the time service are used to maintain a clock for the duration of your use of the program. The timekeeping is checked every minute. If these interrupts are not available they may be provided by an external oscillator or generated internally. Both the absolute and relative timing accuracies may be seriously compromised if the time service is not connected to the program. This is a consequence of the way data are moved to and from various memory buffers by the program. On the other hand, it is still possible to work provided timing accuracy is not critical.

3 Data recording

Images can be stored on either a 110Mb hard disk or a 1600bpi magnetic tape or on both. The image read out from the CCD is not secure until it is stored somewhere, and you are recommended to use the disk as the primary store. Ultimately you will take your data away on magnetic tape. You may record data on disk and tape simultaneously, but this is not recommended since in the event of a crash it may take a long time to get the tape back to the correct position when the program is restarted. If you record on disk only you can copy some or all of the disk files to tape later at your convenience.

3.1 Disk

Assuming an overhead of 20Mb on the hard disk for other programs and data, there are 90Mb available for images. This translates to about 270 full size RCA frames. These image files are referred to simply by means of a running number, though they are stored under a more complex title in a special directory. **All users share the same image directory, so that files created by another observer will be overwritten, though you cannot normally accidentally overwrite your own files.** You should clean out this space the first time you use the program. A running check is kept of the amount of room left on the disk and you will be informed about this during the startup phase and every time a new file is written. It will probably be necessary to erase or overwrite some of your own files in the course of a good week, but this can all be done from within the main program.

3.2 Tape

There is room for about 80 full-sized RCA frames on a 2400-foot, 1600-bpi tape. The magnetic tape driver is loaded during the startup phase of the program. If the tape unit is not switched on, or if the tape is not online, the program will ask whether you want to proceed without the tape or not. You can attach the tape unit to the program later if you wish, but it might be more convenient to do it at the start. The tape, with a write-ring installed, should be threaded on the unit according to the diagram inside the door. Make sure the density is set to PE, press LOAD and ONLINE. The green lights next to WR EN, ONLINE and PE should be lit when the tape is properly mounted and ready for action.

Unfortunately, the EMI tape drive is rather slow, and apart from rewinding, the fastest it will go is about 1 full-sized RCA frame file per 10 seconds. Thus it would take about 10 minutes for the tape to reach the last file in preparation for writing the next one when three-quarters full of RCA images.

3.3 Timing

The approximate time taken for various operations is given below. The readout time scales approximately as the ratio of the number of pixels in the window to the total number of pixels in a normal readout.

Prepare 2.5 sec

Preflash $\sim$ 400 msec for RCA chip

Readout 11 sec for full RCA 360×512 frame

Display $\sim$ 4 sec for full RCA frame

Disk storage $\sim$ 4 sec for a full RCA frame

Tape storage $\sim$ 10 sec for a full RCA frame

4 System Files

There are various files kept by the system as well as files generated by the program and kept in your directory which contain both information relating to your instrumental setup and details of the disk and tape files you have generated. It is not necessary to know much about these in detail, but you should be aware of their place in the scheme of things.

4.1 CCD, Filter wheels, Standard stars

Information relating to the number of rows and columns of the available CCD chips is kept in a file so that when you indicate which chip you are using the relevant details are read into the program. Only the RCA chip, called RCA1, is currently available.

Similarly, information about the filter box is kept in a file. The box has two wheels with 8 holes each. When you log on for the first time you are asked to enter the names of the filters against the filter numbers used by the program. Normally, wheel A contains the standard UBV$(\mathrm{RI})_C$ set and is rarely changed. The second wheel, B, is intended to hold any extra or special filters required. It is important to check what filters are in wheel B even if you have no intention of using any other than the UBV$(\mathrm{RI})_C$ set.

The coordinates of the SAAO E- and F-region standards, as well as of some Magellanic Cloud standards, are kept in a file which is searched if necessary when an object whose name starts with E, F, or C is entered at the start of an exposure. If a match is found the coordinates are displayed on the screen.

4.2 Setup, Disk and Tape logs, Star file, Program files

Your observing run is characterised by a **run number**, which can be found from the CCD log in the dome and which is incorporated into the names of various files. This number is referred to as XYZ in the following paragraphs. It is incremented by one for each successive observer.

The information gathered by the program when you login to your directory for the first time is stored in a **setup file** called setXYZ.up. This contains details of the CCD chip, the filter box and the filter names. It is read on subsequent occasions when you start the program. Its contents can be edited from within the program.

Images stored on the disk and on tape are recorded in **log files**, diskXYZ.log and tapeXYZ.log, and the details can be displayed on the screen or on the printer from within the program. The tape is considered to contain the definitive record of your run, so the tape log should agree with the CCD log in the dome. Generally, not all files recorded on the disk will be stored on tape, so the disk file number from which a tape file was filled is recorded in the tape log for your information. During a run it will probably be necessary to erase or overwrite some disk files. It is much more convenient to recall data from the disk, but there is limited room available.

As you enter new object names they are stored together with their coordinates in a **star file**. This file is searched to find out if an object is already known to the program for your run, and the coordinates are displayed on the screen if a match is found. Stars found in the **standards file** are copied to the star file for convenience. This file can be added to at any time while the program is running and edited if necessary. It is called star.dat.

A CCD exposure involves a number of operations. You may often do the same thing for a whole series of exposures and to save time and energy on keyboard entries, the sequence of operations can be saved as a '**program**' on the disk. This is described in detail later. The 'programs' are called program.AB, where AB can range from 01 to 16, and are recalled automatically whenever GODOT starts up. They are referred to simply by the AB part inside the main program.

4.3 Images

Images are stored on the disk and on tape in binary and are accompanied by a FITS format header which contains details of the exposure. On the disk there is a special directory in which the images reside. Although several hundred may be stored on the disk at once, there is not unlimited space and some may have to be overwritten or erased during your run. The files are referred to simply by number in the main program. There may be some files obtained by the previous observer left on the disk at the start of your run which should be erased from within the main program the first time you log on.

A sample FITS header is shown on the next page. The header associated with the image currently in the Memory can be displayed by using the FITS command in the Utilities menu (see section 6.1.7). The ellipses followed by numbers on the right-hand side of the example do not belong to the header, but have been added to draw attention to a note beneath the listing of the header.

Sample FITS header

```
SIMPLE  =                    T         /
BITPIX  =                   16         /
NAXIS   =                    2         /
NAXIS1  =                  360         / columns
NAXIS2  =                  101         / rows
ORIGIN  = 'SAAO    '                   /
INSTRUME= '1.0M RCA1 CCD'              /
DATE-OBS= '07/06/92'                   /
CTYPE1  = 'RA      '                   /
CRVAL1  =             180.0656         / ra in degrees
RA      = '12:00:15'                   / ra
CTYPE2  = 'DEC     '                   /
CRVAL2  =             -46.1101         / dec in degrees
DEC     = '-46:06:36'                  / dec
UT      = '16:56:34'                   / UT start
ST      = '11:25:09'                   / Sid T start
OBJECT  = ' E580                     ' /
IMAGETYP= ' object'                    / IRAF image type          ..1
FILTERS =                   58         / AB-positions
FILNAMES= ' I4 -'                      / Aname Bname
ITIME   =                6.034         / integration time in secs
PREFLASH=                  400         / time in msec
EPOCH   =               1950.0         / Equinox of RA,Dec
TRIMSEC =  '[  5:322,  1:101]'         / Useful part of data      ..2
BIASSEC =  '[324:359,  1:101]'         / Overscan region          ..3
COMMENT =
COMMENT =
DATASEC = '[  1:360,  1:101]'                                     ..4
CCDSEC  = '[  1:360,230:330]'                                     ..5
END
```

Notes:

1 Used by IRAF during image cleaning and processing

2 Specifies the useful part of the data, in this case columns 5 to 322 and rows 1 to 101, both inclusive.

3 Specifies where the overscan region is to be found, *viz.* columns 324 to 359 and rows 1 to 101, both inclusive.

4 Specifies the area in the FITS file in which data are to be found. In this case the whole 360 $\times$ 101 array contains data.

5 Indicates what part of the full CCD has been read out. In this case it is columns 1 to 360 inclusive, and rows 230 to 330, inclusive. The two lines numbered 4 and 5 are only included for windowed readout.

5 Screen Layout

The screen area is divided into several regions which will be described below and which are referred to as menus or windows, depending on their function. Menus display a list of options which are available at various stages during the operation of the program and which allow one option to be selected. Windows are areas in which messages or the results of measurement or progress reports or prompts for data entry may appear. The menus and windows will be described individually below. The clock is a special example of a window and is dealt with next.

5.1 Clock

The South African Standard Time (SAST) is displayed in reverse video at the top right side of the screen. This clock may be driven in 3 different ways. The preferred method makes use of the 1 kHz pulses from the time service to interrupt the program every millisecond and increment a counter. Alternatively, an oscillator capable of producing 1 kHz pulses may be connected to the system, or failing that the computer's own internal oscillator may be used. The program can detect the presence of external interrupts, and a suffix **e** is displayed with the time if they are there; if the source is internal the suffix will be **i**.

The time service also sends out the SAST and the local sidereal time in coded form and if these signals are detected by the program the SAST will be displayed when the program starts. If the serial time information is not available, the program will prompt you to enter the SAST. You should enter the current time plus about 10 seconds and be prepared to press the **Enter** key exactly at the time you have entered. The SAST will then be displayed in the corner of the screen.

Every minute, the time service emits a minute pulse and this pulse, if available to the program, is used to keep the clock synchronised. This is important since the method used by the program to transfer data between certain parts of the computer's memory requires that it ignore interrupts during the transfer. This will cause the clock to run slow, and more importantly if an exposure is in progress, the program may miscalculate the exposure time. Only if external interrupts are being used can these effects be allowed for and a correction be applied automatically to the integration time. Furthermore, if the minute pulses are available the clock time will be corrected every minute and the time may appear to jump discontinuously at that instant.

5.2 Name Bar

The top line of the screen permanently displays the name and version of both the control program and the Transputer program.

5.3 Message Bar

The second line of the screen is used to display various messages. These may relate to error conditions, or provide information concerning the progress or completion of various operations.

5.4 Frame data

This small area below the Clock shows the size in columns $\times$ rows of the CCD, the type of data being saved in the image store, and an indication of which of full- or windowed-frame modes is in force.

5.5 Windows

Of the 5 windows, the Main, Data, State and RUN windows are on the screen at all times. The Screen window only appears when a selection is made from the ImageDisp menu. It overwrites the RUN window, but disappears when control is returned to the main program (as indicated by the reappearance of the selection bar in the Basic Menu). The function and contents of the windows are described here.

5.5.1 Main

This is the main area through which the observer communicates with the program. All responses to queries from the program are entered here. Pressing the **Enter** key is the usual way of indicating the end of a data item. Occasionally, especially when the expected response is **yes** or **no**, only a single character, **y** or **n**, need be entered without the **Enter** key.

The results of calculations, e.g. when the calculator is being used, or when photometry is being done on a star image, will appear in this window.

5.5.2 Data

The Data window shows the values of several parameters which may be updated from time to time by the program. The titles of the items displayed and a description of the data referred to are given in the following paragraphs:

- Temp(K)

The temperature of the CCD chip is obtained from telemetry signals every time a selection is made from the Basic Menu. You can force the temperature to be read when the Basic Menu is active simply by pressing the **Esc** key. Occasionally a peculiar value may appear here due to noise on the telemetry lines. If it does, check the temperature again by pressing **Esc**. Whenever it is read, the temperature is compared with the expected value. If the two numbers differ by more than 2.5% on three consecutive occasions, the temperature will be displayed in flashing reverse video. This may be an indication that the chip is warming up. If the condition persists, fill the cryostat with liquid nitrogen. Use the Temperature option in the CCD Menu (see Section 6.1.3 for details) to check that the temperature returns to normal.

- Elapsed and ExpTime

  When the shutter opens, the requested integration time appears on the ExpTime line. As the exposure progresses the number of seconds elapsed appears in reverse video on the line above. The count will stop if you hold the exposure, for cloud, say, or if the exposure is terminated. At the end of an exposure, the shutter closes, regardless of what you are doing, but the CCD can only be read out if control is returned to the main program (you may perhaps be manipulating an image, or performing a calculation with the calculator when the exposure ends).

- FiltA, FiltB

  The current position of the two filter wheels together with the names of the filters is given on these two lines. During filter initialization these spaces are filled with ***** in reverse video.

- PrebinHV

  The image recorded on the CCD may be prebinned in both the horizontal (along the rows) and the vertical (up the columns) directions before readout. The number of pixels added together in each of the directions before readout is recorded on this line, horizontal first. Only 2x2 prebinning is available.

5.5.3 State

The entries in this window show the progress of operations relating to the CCD. The window has a set of descriptors on the left side, and in reverse video on the right side is the corresponding status. The descriptors are as follows:

- Purge

  Residual charge on the CCD can be removed by purging, which involves a vertical transfer of charge down the chip but no horizontal transfer. While the CCD is purging the indicator will show ON, otherwise it will be blank. This is not very effective with the RCA chip.

- Prepare

  During a prepare readout, the CCD is read out but the data are not stored. This is a cleansing operation which takes about 2.5 seconds for the RCA chip. The indicator will be ON during prepare readouts.

- Preflash

  Because the charge transfer efficiency of the RCA chip is low at low signal levels, it is necessary to add charge by means of a short exposure to a set of LEDs without opening the shutter. While the lamps are on the indicator shows ON.

- Shutter

  The shutter is normally CLOSED, and the indicator will show OPEN while the shutter is open.

- Exposure

  During an exposure the indicator will show ACTIVE. If it is necessary to pause during the exposure, perhaps because cloud appears, then HOLD will appear and the shutter will close. When the exposure restarts, ACTIVE will reappear.

- Readout

  While data are being read out from the CCD the indicator will show ACTIVE, otherwise it is blank.

- Data

This shows the direction of any data transfer currently in progress. During a transfer to the display monitor the indicator shows –>DISP, to a disk file it shows –>DISK, to tape it shows –>TAPE. When data are recalled from disk or tape the indicator will then show <–DISK or <–TAPE, respectively.

5.5.4 RUN

This window shows information concerning the tape and disk files relevant to the current run. The run number appears at the top of the window. Subsequent lines give the following details:

TAPE# The number of the tape (if any) that is currently mounted on the tape drive.

Nxt The number of the tape file that will be written next.

Now The number of the tape file at the beginning of which the read/write head is positioned.

Lft The approximate number of full-sized tape files that will fit on the unused remainder of the tape. To find the approximate number of windowed or prebinned frames that will fit, multiply the indicated number by:

$$(2880+2*fullrows*fullcolumns)/(2880+2*rowsread*columnsread).$$

Disk

Nxt The number of the next disk file that will be written.

Lft The number of files of the same size as the current setup would read out that could be stored on the disk in the space remaining.

5.5.5 Screen

This window only appears when an item is selected from the ImageDisp menu. Various parameters relating to the currently displayed image are shown. This window overwrites the RUN window whenever the Image Display Menu is selected.

cursor> The x and y coordinates of the cursor when it is visible on the monitor.

inLUT> The number of lookup table that is applied to the data when transferred to the frame-grabber.

dspLUT> The number of the frame-grabber's internal lookup table.

Shape> The shape of the region centred on the cursor which will be used to derive image parameters. It can be either a circle or a square.

Size The size of the measurement region – the diameter of the circle or the side of the square.

Window The part of the data for a full image stored in the image memory store that is displayed on the monitor.

6 Basic Menu

The basic menu appears within a horizontal box on the fourth line of the screen. It consists of 8 headings which categorize 8 sub-menus. Selecting a heading in the basic menu will give access to a number of related commands in a sub-menu. Selecting an item from a sub-menu in turn will either result in some action by the program, eg read out the CCD, or will give access to yet another sub-menu.

Each of the basic selections is described in detail below, but in summary they are as follows:

Filter Allows the filter wheels to be controlled.

Program A 'program' consists of a set of actions to be carried out consecutively by GODOT. Programs can be entered, executed, listed, interrupted, etc.

CCD Most of the functions relating to the CCD, such as readout, open and close shutter, purge, preflash can be carried out separately via this selection.

ImageDisp All functions relating to image display, measurement and manipulation are under the control of this selection.

MagTape Controls magnetic tape access, writing and reading.

Disk Controls storage and retrieval of disk files.

Utilities Various useful functions such as entering star names and editing them as well as a calculator (using RPN, like an HP) can be accessed from this selection.

Exit To leave the program gracefully.

A menu or sub-menu is active if one of the items it contains is highlighted in reverse video. An item may be selected in one of two ways:

(a) by pressing the key on the keyboard corresponding to the first letter of the item;

(b) by moving the highlight by means of the space bar or the arrow keys until it reaches the relevant item and then pressing **Enter**.

Thus, to display an image, you can press **i** or **I** or you can move the highlight until it covers ImageDisp and then press **Enter**. A similar procedure applies to sub-menus. To return from the Basic Menu from any sub-menu, press **Esc**.

6.1 Sub-Menus

When a selection is made from the Basic Menu one of the 8 sub-menus appears, and a final selection can then be made.

> **The Esc key provides a means of exiting from a menu and returning to the Basic Menu without making a selection.**

To choose a menu, move the highlight with the aid of the spacebar or of the arrow keys, or press one of the following keys: **f, p, c, i, m, d, u, e**.

The options available through the 8 menus are discussed in the next 8 sections. There are usually several ways of getting the program to do what you want so it is worth experimenting to find a mode of operation that suits you.

6.1.1 Filters

The filter box has two wheels (wheel A and wheel B) mounted one above the other. The upper wheel (A) has 8 positions for 50mm $\times$ 50mm filters and the lower one (B) also supports 8 50mm $\times$ 50mm filters. There is a limit to the speed with which either of the wheels can be moved, so there is a delay (timeout) associated with the movement from one filter position to the next. The timeout is normally 2000 msec. It can be altered via commands in the Utilities menu though this should never be necessary.

Select the filter menu by pressing **f** or by moving the highlight to the first position of the Basic Menu and pressing Enter. There are three associated sub-menus. The first one has two commands:

- Initialise (**i**)

  The filter wheels are initialised automatically when the program is started up. This involves rotating the wheels to bring filter 1 into the beam. There is a reference mark associated with this filter position, and this mark must be recognised by the program for it to be able to find a given filter. The filter encoders are not absolute so this reference mark is vital for the correct selection of filters. If anything goes wrong with the wheels, you should ask the program to initialise them.

- Move (**m**)

  Select this command to move the required filter into the beam. A sub-menu appears offering a choice between wheel A and Wheel B. To choose A press 'a', and for B press 'b' or move the highlight. A third menu appears offering a choice of filter numbers. Select the one you want by pressing the relevant key or by moving the highlight.

- Dis/En-able filters (**d**)

  If this option is selected the filter wheels are not moved when requested to do so and no checking of the filter wheel positions will occur. It is normally only used for testing the system without the filter box. Select this item again to enable the filter wheels.

6.1.2 Program

Many observing programs involve repeated entry of the same data for successive exposures. It is possible to automate the process, so that once the data are entered, they can be remembered by the program and can be recalled with a minimum of key-pressing on subsequent occasions. The data are stored in a structure called a 'program'. Programs can be stored on disk for recall on subsequent nights. The menu described here allows you to create, modify and run programs.

Select the program menu by pressing **p** or by moving the highlight to the second position of the Basic Menu and pressing **Enter**. There are 12 options in the menu which may be accessed as usual either by moving the highlight and then pressing **Enter** or by pressing one of the keys: **r, t, p, e, a, s, h, c, g, b, l, or d** . These operate as follows:

- Run prog (**r**)

  After you indicate which program you want to run then the sequence of events it specifies is carried out automatically. Depending on how flexible you have made the program, you may have to answer some questions along the way.

  Program 0 is predefined. It contains the following lines (explanation on right):

  Wheel A : 0 Ask which filter in wheel A

  Wheel B : 0 Ask which filter in wheel B

  Purge : -1 Ask how many times to read chip

  Prepare : a Ask if prepare readout to be done

  Preflash: -1 Ask for preflash time (msec)

  Exp Time: 0.0 Ask for integration time

  Sht open: y Open shutter during exposure

  Display : y Display after readout at end

  To disk : a Ask if image to be stored on disk

  To tape : a Ask if image to be stored on tape

  Repeat : n Stop here

  Clearly there is not a lot to gain in using this program rather than executing the individual steps via the CCD Menu. However, once you have decided to do the same thing for several exposures, you can create your own program. Then you can simply run your program with two keystrokes, and sit back while it gets on with the job.

- Type prog (**t**)

You can display a program on the screen with this command. If it is very long it will be shown one page at a time.

- Print prog (**p**)

This command will give a printout of the program. The printer is checked to see if it is online, has paper in it and is ready to print.

- Enter prog (**e**)

This is the way to enter your own programs. The program number will be the next available one, and is incremented automatically as new programs are stored. You can only enter programs into consecutively numbered structures. Answer the questions that appear in the main window. If you want to decide later the value of a particular datum then use the appropriate place-holder as follows:

filter number: 0 ⇒ Ask for details

purge,prepare,preflash: a ⇒ Ask for details

exposure time: 0 ⇒ Ask for details

exposure time: <0 ⇒ Do not open shutter during exposure

display,disk,tape,repeat: a ⇒ Ask for details

The program is automatically stored on disk in your directory as PROGRAM.xy, where xy is 01, 02, etc. The programs are automatically retrieved when you start GODOT on subsequent occasions.

- Alter prog (**a**)

With this command you can edit an existing program. The current method is rather crude, in that the program is deleted and you are required to answer the questions as for the previous command. You should print out the program you wish to edit before using this command.

- Stop repeat (**s**)

You will have noticed that there is provision in a program for repeating the program once the end is reached. In order to stop this repeat mode, use this command. Execution will stop when the program end is next reached.

- Hold (**s**)

If it is necessary to pause, due to cloud, say, then use this command. The shutter will close, and the timer will stop and wait until you either continue or abort the integration.

- Continue (**c**)

  The exposure continues from where it was stopped on hold.

- Give up (**g**)

  If conditions are too bad then you can abort the integration. The shutter will close, but the CCD will not be read out – do not forget to purge or read out before the next exposure. This command can also be used to abort a program at any stage of its operation.

- Bias only (**b**)

  This is a predefined program (no. 17) which purges the chip for 30 seconds and reads it out immediately to give a frame containing the electrical bias only. It is automatically stored on disk. This program should be run immediately before and after a dark-count frame is obtained.

- Long prefl (**l**)

  It is often necessary to use a preflash exposure to give a pedestal of counts on which the object exposure is superposed – to ensure 100% counting efficiency. This preflash exposure must subsequently be subtracted before processing the frame. This is best done by obtaining a long exposure to the preflash lamp and then to subtract a scaled version of it from the object frame.

  The usual preflash time is 300 to 500 msec for the RCA chip. Program no. 18 is predefined to perform a long preflash exposure and is invoked via the **l** command. The exposure time should be 100 times the value you normally use. At the end of the long preflash exposure, the CCD is read out and the image stored on disk automatically.

- Dark frame (**d**)

  Program no. 19 is predefined to produce a long integration with the shutter closed. The chip is first purged, and you are required to enter an integration time (at least 1 hour). After this time, the chip is read out and the frame stored on disk.

You should obtain a bias frame before and after a dark frame. You should obtain at least two consecutive dark frames in order to remove cosmic ray events.

6.1.3 CCD

This menu allows the CCD to be controlled in a step- by-step fashion that is particularly useful when testing the system. There are 13 functions available and they can be selected by moving the highlight or by pressing one of the keys, **1** to **9** and **a** to **g**. A description of each follows:

- Read CCD (**1**)

  The image will be transferred from the CCD to the primary store in the computer. This is a relatively delicate operation during which no other activity should be undertaken (like moving the dome or telescope). No interaction with the program is possible during a readout. A 'confidence box' will appear on the second line of the screen, below and to the left of the SAST label. The number in this box will increment during the readout as an indication that something is happening. It takes about 11 seconds to read out a full frame from the RCA chip. As it is being read out the image will appear on the monitor screen.

- Window on (**2**)

  The start and end lines of the required window can be entered. At each subsequent readout of the chip, only this subset of rows will be transferred from the Transputer to the IBM. The word WINDOWED will appear in the Frame data area at the top right of the screen. Cancel with function **4** (see below).

- Purge (**3**)

  This is a cleansing operation designed to remove any residual charge from the CCD prior to starting an exposure. Charge is moved down the columns but is not read out through the preamplifier. Since only vertical transfers are involved, the whole chip is rapidly emptied of charge. The charge is however left in the readout register and may result in a ramp in the counts at the beginning of the next full readout. It should only be used in conjunction with Prepare under normal circumstances.

- Window Off (**4**)

  This function restores the readout to full-frame mode, and cancels windowed mode. The words Full frame will appear in the Frame data area at the top right of the screen.

- Prepare (**5**)

  This command initiates a dummy readout of the chip. Vertical and horizontal transfers occur as for a normal readout, but the image is not stored. This is the recommended cleansing operation. It takes only about 2.5 seconds since no time is spent digitising the signal.

- Bias On (**6**)

  The readout efficiency of the RCA chip is less than 100% at low signal levels. It is necessary to have 550 electrons in a pixel before its accumulated charge is accurately read out. An exposure can be made to a set of LEDs located behind the shutter to guarantee this count level. The 'Bias On' command allows you to enter an exposure time in milliseconds. For the RCA chip this is normally between 300 and 500 milliseconds. The lamps do not illuminate the chip evenly, so you should check that the required count level is reached all over the chip. It is of course necessary to remove the effects of this preflash before analyzing the image.

- Bias Off (**7**)

  If an exposure time was not specified then you can turn off the preflash lamps via this command.

- Open Shutter (**8**)

  This command allows you to start an exposure and to specify an exposure time which may be as short as 0.3 seconds and as long as you wish. If a time is specified, the shutter will be closed at the end of this period, the CCD will be read out and the image displayed on the monitor.

- Close Shutter (**9**)

  This allows the shutter to be closed if it is open. When the shutter closes, the elapsed time since opening is displayed on the screen.

- Temperature (**a**)

  The temperature in various parts of the CCD cryostat is read continuously and displayed on the screen in a special window. The first line gives the temperature of the liquid nitrogen tank, and should show $\sim$77K. The next line gives CCD temperature, which should be $\sim$158K for the RCA chip, while the last line show the error signal in the temperature servo system. The window disappears when the next menu choice is made.

- Focus Test (**b**)

  Selecting this function prevents the CCD from being read out at the end of an exposure so that a series of exposures can be made on the same frame. The program prompts for an exposure time and then allows you to make an exposure at some focal setting, change the setting, move the image along the chip and then make another exposure for a series of settings. When you have done about 10 exposures, you can then command the chip to be read out. The image will be displayed and a cursor will appear, allowing you to measure the diameters of the set of images.The best focus will be the one giving the roundest, smallest images.

- Prebin (**c**)

  During a normal readout the charge on the chip is moved down vertically by one row at a time. The bottom row is moved into the output register. A series of pulse is then applied to move the charge horizontally, one pixel at a time, into the output amplifier for digitization. A certain amount of 'readout' noise is introduced at each horizontal shift. The relative importance of this noise can be reduced by 'prebinning'.

  Horizontal prebinning involves combining the count in two or more pixels during readout and before digitization. Thus, horizontal prebinning of a flat field by a factor of two would result in an image with half as many columns, each having twice the original count per pixel and the readout noise per pixel will have been only slightly more than without prebinning. The signal-to-readout noise ratio will have been doubled.

  The image can also be prebinned vertically. This involve summing two or more rows in the output register before shifting the pixels horizontally into the output amplifier for digitization.

  Only 2×2 prebinning is implemented with the current Transputer setup.

  This function is incompatible with Windowing, which must be disabled before prebinning can be used.

- Noise Test (**d**)

This command is for test purposes only. It allows the gain in electrons/ADU and the readout noise to be computed from a graded series of pairs of exposures on a constant light source.

- Contin Read (**e**)

  This command is intended for test purposes. It causes the chip to be read out continually.

- Video mode (**f**)

  The CCD can be used as a crude kind of acquisition TV by means of this command. The readout is automatically changed to Prebin mode (windowing is automatically turned off), and successive exposures are made for the time specified. The shutter closes after the time requested, the image is read out and displayed, and the shutter opens for the next exposure. Return to normal mode by pressing any key (preferably **Esc**).

- Waveforms (**g**)

  Allows new readout waveforms stored in a file to be loaded into the Transputer. This is normally only used for testing.

6.1.4 ImageDisplay

This command gives access to all the image manipulation functions. When this menu is chosen, the Screen window appears. This allows you to see the state of several relevant parameters. When the cursor is on the screen its x and y coordinates appear in the window. Note that the coordinate system is such that the origin is in the upper left corner, x increases to the right and y increases down the screen. Due to a peculiarity of the hardware the cursor can only be displayed on even coordinate pairs, though it is possible to move it to all possible positions in the screen data array which has dimensions of 512 rows in y by the number of CCD columns in x. Thus the cursor appears to move in a jerky fashion on the screen even though it is moving smoothly through the data.

The data read out from the CCD are represented by 16- bit numbers. Valid data range from 0 to 32767. Beyond this latter number, data values will appear negative. The frame grabber can only store and display 8-bit data ranging from 0 to 255. Thus, to display an image, it is necessary to convert the 16-bit integers to 8-bit integers. This is done via a look-up table (LUT) of which there are 8 available at present. The frame-grabber has its own set of 8 LUTs with which the 8-bit data can be further manipulated for display. It is worth spending a little time making sure you understand the distinction between the LUTs. The two LUT numbers currently in use are shown in the Screen window. These LUTs will be used until changed via the relevant command as described below. The shape and size of the marker that will be put on the screen when measurements are made on the image are also given in the Screen window. These are also used by default until new selections are made.

There are 10 functions which may be selected by moving the highlight or by pressing one of **s, i, d, c, r, m, f, t, l, w, o, h, x, z, p**. These are described below:

- Show image (**s**)

  The image currently residing in the image store will be displayed on the screen The LUTs used are shown in the Screen window. A representation of the display LUT is given as a vertical bar to the right of the image. The original data values corresponding to the first and last values in the LUT are displayed at the top and bottom of the bar.

- ImageLUT (**i**)

  There are 9 image LUTs. The first 7 allow various sets of 8 consecutive bits in the image data to be displayed. Suppose two pixels have collected 21844 and 10922 counts, respectively, during an exposure. These two numbers are represented in binary as follows (most significant bit on the left):

21844: 0101 0101 0101 0100

10922: 0010 1010 1010 1010

ImageLUT 0 selects the rightmost 8 bits (bits 0 to 7) of each for display. Thus these two pixels are represented as having 84 and 170 counts, respectively - the pixel with more counts will appear fainter on the screen. **ImageLUT 1** will select bits 1 to 8, and the pixels will appear to reverse in brightness, the first having 179 and the second 84 counts. **ImageLUT 6** displays bits 6 to 13.

ImageLUT 7 divides the data by 2 and then displays the logarithm of the result, scaled to fill the range from 0 to 255. This LUT has the effect of enhancing low level detail, while also showing the brightest pixels as well.

ImageLUT 8 allows you to set the minimum and maximum counts to be displayed as intensities in the range from 0 to 255. Counts less than the minimum are displayed as 0, and those above the maximum as 255. This allows you to enhance the contrast so that detail in a particular recorded intensity range can be seen.

- DispLUT (**d**)

  The frame-grabber has 7 hardware LUTs which can be used to manipulate the image further.

  DispLUT 0 shows the image on a grey scale with 0 as black and 255 as white.

  DispLUT 1 shows the image in reverse video, with 255 as black.

  DispLUT 2 is ...

  DispLUT 3 displays ...

  DispLUT 4 displays the image in colour, with 0 as blue and 255 as red with a rainbow of colours in between. It will often be useful to use this DispLUT as details may be seen which are not well represented on a grey scale.

  DispLUT 5 is not particularly useful

  DispLUT 6 and 7 are used by the program in displaying graphical data as coloured overlays on the image.

- Circle (**c**)

The marker displayed will be a circle. Its diameter in pixels will be prompted for. An odd number greater than 1 and less than 61 can be entered. The program will round an even entry up to the next odd number.

- Rectangle (**r**)

The marker will be a square, the length of whose side should be chosen to be between 3 and 61. The program will round an even entry up to the next odd number.

- Measure (**m**)

The cursor will appear on the screen and may be moved vertically and horizontally by means of the arrow keys or the 2,4,6,8 keys on the keypad, or diagonally with the 1,3,7,9 keys on the keypad. The **speed** of motion is initially 8 pixel per step and can be reduced by factors of 2 by successive depressions of the **F1** key to give 4, 2 and 1 pixels per step, respectively. Use the **F2** key to increase the speed by factors of 2 over the range 2,4 and 8 pixels per step.

A line of text (in reverse video) appears in the Message Bar at the top of the screen to remind you of the possible commands when the cursor is on.

Pressing **Ins** on the keypad will cause the current symbol centred on the cursor cross to be put on the screen. The statistics of the pixels within the area outlined by the symbol will be displayed on the screen. A crude form of aperture photometry can be done with this command. It is also valuable in checking bias and sky levels, uniformity of background, for possible image saturation and in determining exposure times for flat fields. A magnitude is also given. The zero point is stored in the program, and has been adjusted to give approximate agreement with E-region star V magnitudes. No account is taken of air mass or colour equations in producing this magnitude.

- Fit Gauss (**f**)

This gives information about image structure. A two- dimensional Gaussian is fitted to the image indicated by the cursor. Data from within the area outlined by the current symbol, displayed on the screen, are used in the calculation. The full width at half maximum (FWHM) is given in pixels along with the peak count and the centroid for the Gaussian fitted. A magnitude is also given. The zero point is stored in the program, and has been adjusted to give approximate agreement with E-region star V magnitudes. No account is taken of air mass or colour equations in producing this magnitude.

- Transect (**t**)

  This command allows you to display the variation of signal count along an arbitrary line drawn through an object. A plot of count versus pixel is shown superimposed on the image on the display screen. There is no restriction on the length of the line.

- List image (**l**)

  The counts in a 7×7 box centred at the specified position are listed on the screen.

- Window (**w**)

  This allows a subsection of the full CCD image that is currently stored in the 1Mb Memory to be displayed on the screen. It is intended for use mainly with chips larger than the RCA one, which overfill the 512×512 space available in the frame-grabber. Choosing values for left and right columns and top and bottom rows other than the default 0,511 and 0,511 will lead to marginally faster display times. The current window is displayed in the Screen window. This should not be confused with windowed readout of the chip.

- Orientation (**o**)

  Use this command to find out the angle between the axes of the chip and the cardinal directions. It involves obtaining an image of a star set first near one edge of the chip (usually E) and then near the other (usually W), both on the same frame. After the readout, a cursor appears allowing you to mark the positions of the two images and hence the orientation to be calculated. This function may be used in conjunction with the image obtained during the focus test at the start of the night.

- Histogram (**h**)

  This command allows you to see a plot of a histogram of counts in a specified part of the chip.

- XYoffset (**x**)

Used in conjunction with the autoguider program. You can indicate a star on the monitor and then move the cursor to the place on the chip you would like it to be. The program will compute new X,Y coordinates for the autoguider to allow it to be reset to bring the star to the place indicated without the observer's having to leave the warmroom. The orientation of the chip should have been determined beforehand, otherwise it is assumed to have its axes aligned north-south and east-west.

- Z-LUTrot (**z**)

  Allows the LUT to be rotated to alter the appearance of the display on the monitor. The rotation is controlled by the **o, p, l, q** keys on the keyboard. This function may help reveal features or detail in the image not obvious with the current standard LUT.

- P-Test (**p**)

  Allows various test patterns to be put on the monitor in order to test its performance.

6.1.5 Mag Tape

To take data away from the telescope it is necessary to store it on 9-track magnetic tape. Data are normally stored on disk only while you are observing. When you want to record on tape it is best to have the drive switched on and a tape mounted at program startup time, but you can also start recording on tape after the program has started.

This menu gives you complete access to the magnetic tape system. There are 13 options, which may be selected by moving the highlight or by pressing one of the following keys: **w, r, i, g, l, b, t, f, s, p, e, a, v**.

- Write file (**w**)

  Files are written consecutively on tape and numbered accordingly. It is not normally possible to overwrite a file, so that if the tape head is not positioned at the end of recorded data when requested to write a file, the tape is first advanced until the end of data mark is reached before writing. The file number and the name of the object recorded therein is displayed on the screen as the tape is moved to the end of recorded data.

  Tape files should be written at a density of 1600 bits per inch (the PE switch should be depressed and the light on) and there is room for about 80 full images obtained with the RCA chip. A check is made for end-of-tape, and you will be notified if you reach it while writing data, but you should not try to put too much on any tape.

- Read file (**r**)

  To read a file from tape it is only necessary to specify the file number on the tape. The first file is number 1. Data read from the tape are stored together with the FITS header in the primary image store, so that any image already there is overwritten.

- Init tape (**i**)

  Before data can be written on a tape, the tape must be initialised. This involves writing two consecutive end- of-file (EOF) marks near the beginning of the tape. A double EOF mark is the way the tape read head recognizes the end of valid data. When a new file is written, the second EOF mark is overwritten by data and two new EOF marks are written at the end of the file to mark the new end-of-data.

  Initialising a tape effectively destroys any data already on the tape so this command should be used cautiously. You will be prompted to confirm that you really want to carry on when you select it. If you do want to carry on you **must** answer **yes** in full. Any other reply will be taken to be **no**. If you accidentally initialise a tape containing useful data, don't panic. Remove the tape from the unit and put it aside. There is software available in Cape Town for recovering the data.

- Go to file (**g**)

  This command allows the tape to be advanced or rewound to bring the beginning of a specified file to the tape read head. It is not necessary to use this instruction first when reading a file.

- Last file (**l**)

  The tape is advanced until the tape reaches the end of recorded data and the head is positioned ready to write the next file. It is not necessary to use this command before writing a new file.

- BOT (**b**)

  The tape is positioned so that the head is next to the beginning of tape (BOT) mark - a piece of reflecting metallic foil stuck on the tape.

- Tape rewind (**t**)

  When a tape is full, use this command to rewind it prior to mounting a new one.

- First file (**f**)

  This command provides a rapid means of getting the tape to the first file written. It is quicker than requesting file number 1.

- Show log (**s**)

  Whenever a file is written to tape, an entry is made in the tape log file giving the tape and file number, the object's name and coordinates, the UT of starting, the integration time and the disk file, if any, in which the data are also stored. An abstract of this file can be displayed on the screen via this option.

- Print log (**p**)

  The tape log file can be printed for ease of reference. The printer must of course be switched on, online and there must be paper in it.

- End-fixup (**e**)

  If anything goes wrong during a transfer of data to tape, the file currently being written may not be correctly terminated, ie, the double end-of-file (EOF) marks which indicate the end of valid data may not be written. In this case, the end-of-data cannot be found and it will not be possible to write any more data on the tape unless remedial action is taken. This command allows the end-of-data to be re-established. It is necessary to consult the tape log to find the number of the last file successfully stored. The program will prompt you to enter this number whereupon the tape will be advanced to the end of that file and a double EOF will be written. This will effectively destroy any data beyond that point. The file that was being written when things went wrong can then be re-written. Since this command can result in loss of data, be careful when using it.

- Attach (**a**)

  If for some reason the tape unit was not switched on at startup, the tape interface board will have been logged as absent and it will not be possible to write data to tape until the tape is introduced to the program. This command provides a means of doing this. Switch the tape drive on, mount the tape with a write ring installed, press LOAD and ONLINE. This command **must** be used if the tape unit is only switched on and a tape mounted after the program is started.

- Verify (**v**)

  This allows you to check that the number of bytes stored on the tape for each file is as expected. A table is output to the screen giving the tape file number, the name of the object, the expected number of byte, the number found on the tape, and and indication of whether the correct number was found (OK) or not (BAD plus a beep from the computer). If you find any BAD files, it would be prudent to copy all files to another tape.

6.1.6 Disk

Data read out from the CCD are not safe until stored on disk or tape. There is a 110Mbyte disk in the PC so, assuming 20Mbytes are in use for programs, etc, there is room for about 270 full RCA images to be stored. This is probably more than enough for a whole night's data, so in general you should store every image. Functions are available for cleaning up the image store directory from within the main program when there are too many files on the disk.

There are 6 items in the Disk Menu, which may be selected as usual with the highlight or with the following keys: **s, g, t, p, d, c**.

- Save image (**s**)

  Images are stored in a special directory and are named in a characteristic way, but all you have to remember is the file number. The next file number to be used is always visible in the Data Window, and once a file has been written, the program announces how many more files can be stored in the space left on the disk. If there is room for only one more file, you will be prevented from writing any more until you delete some files. You may first want to store some files on tape with the Disk–>Tape function, before using Cleanup to delete some files. The data stored on the disk come from the primary image store, and are accompanied by the FITS header which was constructed at the end of the exposure.

- Get file (**g**)

  As with writing a file, reading one simply involves providing the program with a file number. The FITS header is read into the header store and the data into the primary data store in the PC, so the image already in the store is overwritten. The name of the object is displayed on the screen when the file is read to provide a check that you have the file you want.

- Type log (**t**)

  The first time you use the program and provide a run number, a disk log file is created in your directory. Every time a file is saved on the disk, this log file is updated with the file number, the name and coordinates of the object, the starting UT, the integration time, the preflash time and the date. An abstract of this information can be displayed on the screen.

- Print log (**p**)

The disk log can be output on the printer for ease of reference. The program will check to see if the printer is in a suitable state for printing, and you will be prompted to do something about it if it is not switched on, offline or out of paper.

- Disk–>Tape (**d**)

  If you are recording on disk only then you will at some time wish to dump files to magnetic tape – because there is no more room on the disk, perhaps. This function allows you to store several files at once, so you are prompted for a starting and finishing file number. Obviously, the tape must be mounted and attached to the program for this operation to be possible. Be careful if you are near the end of the tape and do not try to write more than the tape will hold.

- Cleanup (**c**)

  At some stage you will run out of disk space and will have to delete some files before more can be stored. This function will prompt for a beginning and ending file number for a range of files to be deleted. You do not have to delete consecutive files, but it will be easier to keep track of the remaining files if you do.

6.1.7 Utilities

Several miscellaneous functions are available from this menu. They may be accessed by moving the highlight or by pressing one of the keys: **i, c, a, e, n, t, f, b, r, s, d, x**.

- Int Time (**i**)

  This function allows the integration time to be changed during the course of an exposure. Simply enter the new time when prompted to do so. The command is ignored if an integration is not either in progress or in the hold state.

- Calculator (**c**)

  You may have forgotten to bring your calculator along. With this function all is not lost. It provides a simple RPN calculator (like an HP) which besides the usual add, subtract, multiply and divide also gives change sign, $\log_{10}$(x), magnitudes (-2.5log(x)) and 10^x. An entry is terminated by the **Enter** key, and whenever a part of the calculation can be completed the intermediate result is displayed on the screen. The allowed operators are shown on the second line of the screen while the calculator is in use. To switch off the calculator press **q** and **Enter**.

- Add comment (**a**)

  There is provision in the FITS header for a comment of length up to 60 characters. This comment should be entered during the course of an exposure. At any other time this command is ignored.

- Edit (**e**)

  This function gives you the chance to change the setup information relating to the filter wheels which is read by the program when it starts up or to change the coordinates of a star in the star file.

- New star (**n**)

  At the start of an exposure you are prompted for a star name. If this name is not already in the star file, it is stored for future reference. You can also enter star names by using this function. You are prompted for name, coordinates and equinox. Pressing ENTER on its own when prompted for a name will allow you to exit from this function.

- Type stars (**t**)

  This command allows you to display the contents of the star file on the screen, or to send it to the printer.

- FITS header (**f**)

  This command allows you to see on the screen the FITS header attached to the data currently in the 1Mb image store.

- Bias subtract (**b**)

  It is possible, though not currently recommended, to save only overscan-subtracted images. You can change to subtract mode with this command.

- Read News (**r**)

  Changes, updates, corrections, etc to the program which have not yet been incorporated in the manual will normally be described in a news file, which can be read with the aid of this command.

- Sound ON/OFF (**s**)

  This command toggles off and on the sounds made to signal various operations of the program. For peace and quiet, press **s**. When you start dropping off to sleep, press **s** again to start up the noises again.

- Debug ON/OFF (**d**)

  Used only for test purposes.

- X Row FFT(**x**)

  Diagnostic function. Periodic coherent noise introduced by the electronics when images are read out can be detected and characterised with the help of this function. Input parameters prompted for are start and end rows, columns over which the signal is to be averaged, and starting frequency bin for display of the power spectrum.

6.1.8 Exit

To leave the program, simply press **e**. In case you do this accidentally, you are asked to confirm that you want to stop.

7 Copying Data to Tape

The best method of copying data to tape is to use the Disk–>Tape facility in the Disk Menu. This will allow you to transfer a large number of consecutively numbered files to tape at once. You should make 2 copies of your data – one for yourself and one for the archive in Cape Town. The latter is most important. If anything goes wrong with your data tapes, you will be able to recover the data from the archive tapes, which are kept safely under controlled conditions in Cape Town.

If you start the program with the tape OFFLINE, or not switched on, then you must first mount the tape on the tape unit and switch it ONLINE. Then do the following:

- Select the MagTape menu
- **Attach the tape** (see Section 6.1.5).
- If it is a new tape, you must then **Initialise** it (see Section 6.1.5).
- Select the Disk menu
- Choose Disk–>Tape and answer the questions

Labels for the tapes are kept in a drawer next to the tape unit. You are requested to bring all the write rings and plastic tape spacers back to Cape Town for recycling.