Appendix E

Observing with IMPOL - README

Notation

Below given are examples of notation used here to indicate whether a particular command refers to DOS (instrument control and data-acquisition), UNIX or IRAF.

C:\impol>	$\Longrightarrow$	DOS
pluto(anr):	$\Longrightarrow$	UNIX
cl>	$\Longrightarrow$	IRAF

E.1 Homework

Mounting a CD in the drive

Assume that CDROM drive is connected to a machine called *flora*. Mounting the drive involves, inserting a CD into the drive and typing the following from any machine that has network access to flora.

```
pluto(anr):rsh flora cdmount
```

Precess coordinates using IRAF

If the coordinates of the required field are in epochs other than J2000, precess them to J2000. IRAF has a task which allows to do this. For example to precess from 1950 coordinates to J2000 coordinates, do the following.

```
cl>astutil
as>precess STDIN 1950 2000
5:10:32.1 -20:33:17
```

The precessed coordinates will be printed on the screen. Now another pair of coordinates may be entered and so on. To exit from the task, press ^D.

Obtaining digitized sky maps from Palomar Sky Survey CDROM archive

Mount any of one of the sky survey CDs. Go to a directory where there is enough space to keep an image. Type

```
pluto(anr):/user1/vam/getimage/getimage
```

Enter a filename, centre coordinates of the required field and the field size in the format indicated. You will be prompted to mount a particular disk which contains the required field. Mount this disk and press carriage return. The FITS file will be stored in the current directory. To convert it to an IRAF image, go to the directory (from within IRAF) and type

```
cl>rfits fitsfile * iraffile
```

An IRAF image will be created which contains the field.

Marking the sky map with equatorial coordiantes

The $[-*, *]$ argument of the first command below flips the x coordinate of the IRAF image, while displaying it.

```
cl>disp iraffile[-*,*] 1
cl>stsdas
st>analysis
an>gasp
ga>makewcs iraffile
ga>bye
an>bye
st>graphics
gr>sdisplay
sd>disc iraffile
gr>bye
an>bye
st>bye
```

Obtaining HST Guide Star Catalogue graphs of a region

Mount the correct CD in the drive. From within IRAF type

```
cl>stsdas
st>analysis
an>gasp
ga>regions
```

The user will be prompted to enter the center coordinates, field size etc. A table showing the details of guide stars present within the region will be printed on the screen and the output will be displayed on the graphics display of IRAF. To obtain the table in a text file edit the appropriate parameter of the "regions" task. To obtain a printout of the graph, type

```
ga>regions >G metafile
ga>stdplot metafile
ga>bye
an>bye
st>bye
```

E.2 At the observatory

E.2.3 Observing

Initializing the instrument control software

Once the instrument has been powered on, the software may be started by going to the impol directory in the instrument control PC and typing

```
C:\impol>impol
```

The software will first establish communication with the instrument at the telescope. On success, the user is asked whether it should go ahead with initializing the instrument. Answer "y" if you are running the software for the first time after switching on the power supply or after resetting the IMPOL control box. Once initialized, you can skip this step by typing "n", even if the PC has been powered off, in between, for some reason and you are starting the software afresh. The initialization takes a few minutes to complete and the user is informed of the progress. Once it is complete, the user is asked whether it should move the half-wave plate and the probe to "zero" position. Answer "y", everytime the software is started up.

The user is now given the option of choosing between the auto or manual mode of operation, but only the manual mode has been implemented now. Another option, to exit the software, has been provided during its debugging stage and has not been disabled since. Then the software will display the name of the default parameter file and ask the user to name a new file, if necessary. This is the file from which the equatorial

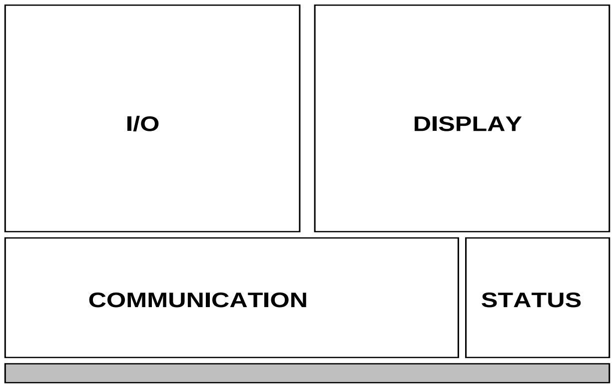

Figure E.1: The windows displayed by the instrument control software.

coordinates of the observation fields are read. The menu bar which allows the user to switch the software to the half-wave plate (HWP) control or tracker (TRACKER) control modes, is displayed at the bottom of the screen.

Using the instrument control software

The software displays four windows on the screen and a menu bar at the bottom (see Fig. E.1). At any menu level, except at the main menu, pressing <ESC> takes you back to the previous menu. At any stage, if <Alt - x> is pressed, the software exits immediately. The hot keys which allow to select a menu option are highlighted in green on the menu bar. For many of the operations, the values of one or more parameters will have to be set. Once the appropriate menu option is selected, these parameters along with their current values are displayed in one of the windows. To change a particular parameter, press the corresponding highlighted letter, enter the new value and press <RETURN>. The new value will now be displayed. Some of the parameters, just toggle within a finite number of options. In those cases, just pressing the corresponding highlighted key successively, allows the user to toggle through the options. The structure of the software is described below. An item is marked with a star, if it has a sub-menu and the options of the sub-menu will be discussed subsequently.

Main menu

Restart – Restart the software.

HWP⋆ – Switch the software to half-wave plate control mode.

Tracker⋆ – Switch the software to acquisition and guidance control.

CCD – Switch the software to main CCD control mode (not implemented).

Exit – Exit the software mode

HWP

Rotate – Rotate the half-wave plate by a specified number of steps in a specified direction at a specified speed. After this option has been selected, the user is prompted to press 'g" to start motion or <ESC> to cancel rotation. A message on the screen indicates that the motion is in progress and once it is over, the display of the current HWP position is updated.

Move to position – Move the HWP to one of the four positions ($0°$, $22.5°$, $45°$, $67.5°$). With this option, the HWP is first moved to $0°$ position by making use of the opto-electronic marker and then moved to the required position.

<ESC> – Return to the previous menu.

Tracker

$\uparrow, \downarrow, \leftarrow, \rightarrow$ – Move the probe by a specified number of steps, in a specified direction at a specified speed. The convention is $\uparrow$ – +X (CW), $\downarrow$ – −X (CCW), $\rightarrow$ – +Y (CW), $\leftarrow$ – −Y (CCW). Once the arrow key is pressed, the probe is moved and the display of the current probe position updated.

Zero – Move the probe to zero position.

Point$\star$ – Menu which allows to position the probe using the equatorial coordinates of the field center and the guide star. This menu also allows moving the telescope by activating the relays which are used by the auto-guider to correct the telescope pointing.

Grab$\star$ – Menu which allows to acquire an image with the ST-6 CCD, display and examine. The auto-guiding may be started from within this menu.

<ESC> – Return to the previous menu.

Point

$\uparrow, \downarrow, \leftarrow, \rightarrow$ – Move the telescope by activating the relays. The convention is $\uparrow$ – +X (higher RA), $\downarrow$ – −X (lower RA), $\rightarrow$ – +Y (higher DEC), $\leftarrow$ – −Y (lower DEC). The relay is activated for 1s, every time an arrow key is pressed.

Observation No – Select the equatorial coordinates corresponding to the particular observation number.

Program – Change the equatorial coordinates of the field center.

Track – Change the equatorial coordinates of the guide star.

Go – Position the probe at the offset corresponding to the above coordinates.

Misc – Allows to set the values of four parameters, namely the Z_X, Z_Y, $G_X = 15 \times G_Y$ (see page 138).

<ESC> – Return to the previous menu.

Grab

Show$\star$ – Display the image that was last acquired with the ST-6 CCD.

Hunt$\star$ – Allows to set the various parameters related to auto-guiding and to start auto-guiding.

Misc – Allows to set parameters related to the exposures taken with the ST-6 CCD. The default values are adequate most of the time, it is preferable not to change these parameters.

<ENTER> – Take an exposure of the guide field with the ST-6 CCD. The exposure duration, type of frame (whether shutter is to be opened or not – light or dark frames, while taking an exposure), and the pixel coordinates of the part of the CCD frame to be downloaded to the instrument control computer, may be specified before taking an exposure. It can also be specified whether an earlier acquired dark frame is to be subtracted from the acquired image and whether it is to be displayed automatically, after downloading to the computer. The "Wait time" is the number of seconds after pressing <ENTER>, which the computer waits before beginning to take an exposure.

<ESC> – Return to the previous menu.

Show

Display – Display the image that was last acquired with the ST-6 CCD. A cursor which is activated by the arrow-keys, is provided to check the pixel values of the image. There is also a provision for setting the contrast in the display using the "Background" & "Range" or "Auto-contrast" parameters. Background is the pixel level which corresponds to the minimum grey level on the screen, while Background+Range, corresponds to the maximum grey level. Once these values are changed, toggle "Auto-contrast" to "no" and then press "d", to obtain a display with the new contrast settings. Toggling "Auto-contrast" to "yes", makes the background and range settings ineffective.

Save – Save the image which has been last acquired with the ST-6 CCD. The image is saved as an ASCII file.

<ESC> – Return to the previous menu.

Hunt

Go⋆ – Start auto-guiding. The X speed and Y speed parameters allow to set the gain of the feedback loop (telescope movement in arcseconds for each second of relay activation time). If the X flip option is set to “yes”, the relay activation scheme is flipped with respect to the default , that is the +X relay is activated in place of −X relay and vice-versa. Similarly, for the Y flip option. “Seeing” allows for the change of image scale on the ST-6 CCD if the probe designed for good seeing conditions is used. “Nod throw” decides the amount of stagger to be introduced in the telescope pointing while auto-guiding. “Hunt box size” allows to set the size of the box used for centroid calculations. “Calibrate” option is disabled now. If “Log track error” is set to “yes”, then a log file is created which contains information regarding the centroid shifts and relay activation times during each loop of auto-guiding.

<ESC> – Return to the previous menu.

Go

Rotate – Rotate the half-wave plate by a specified number of steps in a specified direction at a specified speed. A message on the screen indicates that the motion is in progress and once it is over, the display of the current HWP position is updated.

Zero – Move the HWP to one of the four positions (0°, 22.5°, 45°, 67.5°). With this option, the HWP is first moved to 0° position by making use of the opto-electronic marker and then moved to the required position.

<ESC> – Stop auto-guiding. Return to the **Grab** menu.

Initializing the data-acquisition system

Once the instrument has been powered on, the initialization is carried out by going to the impol directory (which should contain the files chcom2.exe, vterm.exe, vterm.set and accept.bas) in the data-acquisition PC and typing

```
C:\impol>chcom2
C:\impol>vterm
```

Press the space bar on the keyboard. The message “” should now be displayed on the screen. If it doesn't, reset the CCD controller. Press space bar again and the message will appear. Then press <Alt - t>. Now a barrage of text will flow across the screen, which will end with the prompt “>”. Now press <Shift - a>. The screen will display “>B”. Once this happens, the data-acquisition system has been initialized. Press <Cntrl - Break>.

Editing the parameters for exposure control

The parameters which control the exposure are read from a file by the data-acquisition software. A utility (edit1.exe) is provided to create/modify parameter files. To start this utility, type

```
C:\impol>edit1
```

The user is asked for the name of the parameter file which is to be modified (otherwise the utility creates a file with a default name) and then the file is read. The parameters are displayed along with a serial number and their current values (their default values, if it is a new file). To edit a particular parameter, type the corresponding serial number and press <RETURN>. After modifying the parameter, press <RETURN> to confirm the new value. Then user may modify another parameter or press 0 to exit the utility. The important parameters in this list are the ?? and the 11^{th}, which decide the status of the shutter (open/closed) during the exposure and the exposure duration respectively. The exposure duration is set as an integral multiple of 55 ms.

Acquiring, displaying and storing data

The data-acquisition software allows to acquire take an exposure, acquire the data, display and examine it and finally save it in the hard disk, if required. To start this software, go to the correct directory (which should contain the files ccd_new.exe and svga256.bgi) and type

```
C:\impol>ccd_new
```

The user is requested to give the name of the parameter file to be used for the exposure. Once the exposure is taken and the data is acquired, it is displayed on the screen. The user can, then, use the arrow keys to move a cursor around on the image and see the pixel values (displayed in hexadecimal notation). If the <Cntrl> key is kept pressed while using the arrow keys, the cursor moves faster. Press "q" or "Q" to quit the display. Then the user is provided three options

1. Display
2. Save
3. Continue
4. Quit

To select an option press the corresponding hot-key indicated in capital letter. Choosing option 1, allows the user to set new contrast levels (lower and upper pixel values which correspond to the minimum and maximum grey levels on the display) and go back to the display mode. Option 2 allows the user to specify a filename and save the data in the hard disk. Option 3 allows to continue with taking another exposure. Selecting option 4 allows to quit the software.

E.3 Data reduction

Passing/Editing the parameters needed for a task within IRAF

The IRAF editor 'eparam' allows to modify the value of any IRAF task, with the following command :

```
cl>epar taskname
```

To modify the value of a parameter, take the cursor to the corresponding row using the arrow keys, type in the new value and press $< \mathrm{CR} >$. To confirm the new values and exit from the editor press $\hat{\mathrm{D}}$. Some parameters (called psets) of certain tasks will have a subset of parameters. To access a parameter in a subset, take the cursor to the corresponding pset and press ':e'. The contents of the subset will then be loaded in the editor, which can then be modified as above.

Converting FITS files to IRAF image files

To convert a FITS file called fitsfile to an IRAF image called iraffile :

```
cl>rfits fitsfile * iraffile
```

If the names of all the FITS files are listed in a file called 'ftslist', and the corresponding IRAF image names in another file called 'imlist', the conversion to IRAF images can be done with the following command. This will take the first file in ftslist and create an IRAF image file with the first name in imlist and so on.

```
cl>rfits \@ftslist * \@imlist
```

Finding centres of stellar images in a frame, using DAOFIND

Edit the following parameters, before running the DAOFIND task. *Image* is the name of the frame; *output* may be set to *default*. *datap* is a pset, which defines the data dependent parameters of which the relevant ones are scale = 1; *fwhmpsf* to be set to the FWHM of the stellar images; *sigma* to be set equal to the approximate standard deviation of sky pixel counts in the frame; *datamin* to be set a few sigmas below the typical median sky counts and *datamax* to be set to the maximum useful data value. *findp* is another pset in which the only relevant parameter is *threshold*, which defines the threshold (in number of sigmas over mean), above which DAOFIND will look for stellar images. To run DAOFIND, type

```
cl>digiphotx
di>daophotx
da>daof
```

If the parameter *output* is left to *default*, the result of running DAOFIND will be written in a file with name *framename.coo.1*. A more detailed description of DAOFIND and its parameters are given in the help files for DAOFIND, datapars and findpars and can be obtained by typing, say

```
cl>help daofind
```

Finding shifts between frames and creating stellar coordinate files

The GETCENTERS task may be used for this purpose. The relevent parameters are : *images* which should be the name of a file (with the prefix '@') containing a list of the frames to be used by the task, for example '@imlist' (see also Sec. D.3). The first frame in the list is used as the reference frame for finding the shifts. *centers*, which defines the names of the output files in which the stellar coordinates are to be written, may be set to *default*, whereby the coordinates will be written in files with the naming convention *framename.ctr.1*. *findstars* may be set to *no*. *coords* should be the name of a file which contains the exact coordinates of the stars, measured in the reference frame. *shiftcoords* should be the name of a file which contains the approximate coordinates of a few isolated, prominent stars. *shifts* is the name of a file in which the determined shifts between the frames will be logged. *bigbox* is the size of the box used for an initial crude centre determination of the stellar images. *boxsize* is the size of the box used for accurate centre determination. GETCENTERS make use of the IRAF task IMCENTROID for finding the shifts between the frames.

Doing photometry and determining the ratios $R(\alpha)'s$

The task MKRATIOS may be used for this purpose. The parameter *images* is the same as above – the name of a file (with the prefix '@') containing a list of the frames to be used by the task, for example '@imlist'. *ctrlist* is the input list of stellar coordinate files. Setting this to *default*, will use the output files which were created by the GETCENTERS task above.

polfile is the name of the file in which the calculated fluxes, ratios etc. will be finally written to. *dophot* is to be set to *yes* to make this task do photometry on all the frames, using the DIGIPHOTX.DAOPHOTX.PHOT task. This parameter may be set to *no*, if photometry has already been done on the frames. *darkcount* sets the zero level of the CCD counts. The output of the photometry task is usually contained in files with the naming convention *framename.mag.1*. *photlist* may be set to *default* to let MKRATIOS use these files.

dosort is to be set to *yes* to make this task identify stellar image pairs (ordinary and extraordinary) from the photometry output files and write the the results in a new set of photometry files. The names of these new files are created by prefixing a letter, indicated by the *prefix* parameter, to the names of the photometry output files. Two stellar images are considered to form a pair only if their x-coordinate difference is less than *xdiffmax* and their y-coordinate difference lies between *ydiffmin* and *ydiffmax*.

fitskypars is a pset, in which there are three relevant parameters. *salgorithm* refers to the sky fitting algorithm to be used for determining the sky value. *median* has been found to be the optimum choice. *annulus* refers to the inner radius of the annulus around the star from where the sky is to be calculated. *dannulus* refers refers to the width of the above annulus. If a constant value of sky is to be used for all the stars, this value may be set in *skyvalue*.

photpars is another pset, in which the main parameter of relevance is the radius of the photometry aperture to be used. Typically, this is set equal to the FWHM of the point-spread function. *zeromag* is another parameter which can be used to add a zero-offset to the magnitude values reported.

More details of the PHOT task and the associated parameters are available with its help documentation in IRAF.

Determining FWHM of PSF and the standard deviation of sky counts

A task useful for this purpose is DAOEDIT. Display any one of the frames and give this frame as *image* parameter of DAOEDIT. After starting the task, take the cursor to a star on the display and press 'r'. A radial profile of the star will be plotted in the graphics window. The median sky value within the annulus chosen in *photpar* pset, also will be reported. Press 'q' to quit this task. More details are in the IRAF help documentation.

Determining polarization values using DOPOL

The parameter *ratfile* is the input file containing the ratios $R(\alpha)$, the star and sky fluxes etc, for each star. This file, if edited, should retain the same format as is produced by MKRATIOS task. *polfile* is the name of the file in which the polarimetry table is to be written to. If *eliminate* is set to *yes*, a second round of fitting is done, after eliminating those ratios which are more than *threshold* sigma levels away from the results of the first fitting. The *polfile* will then contain the results of this second fitting round and *nratfile* file will be a copy of *ratfile*, but with the eliminated ratios marked as zeroes.

Overlaying a vector plot on a Digitized Sky Survey image using DRWVEC

Display the digitized sky survey image. Display any one of the frames from IMPOL. *vecfile* should be set to the name of a file containing polarimetry output data in the format produced by DOPOL. If *readcur* is set to *yes* the positions on the display where each vector is to be marked should be indicated by the cursor. The corresponding coordinates are then appended to *posfile*. However, if *readcur* is *no*, the coordinates are assumed to be available in *posfile* and the vectors are marked at the corresponding positions on the display. *scale* is a simple multiplying factor which allows to adjust the length of the vectors marked. *dvpar, pltpar, axispar, wcspars* and *wlpars* are psets which define various parameters related to the graphics and image displays. More details about these are available as help documentation in IRAF.

vecfile is the file which contains polarimetry table, *ratfile* is the file which contains the corresponding ratios etc. produced either by MKRATIOS or DOPOL. If *drwerr* is to set to *yes*, error bars are marked on the graphics output window, one which is equal to twice the error calculated from the dispersion in the ratios and the other one equal to twice the error calculated from photon noise calculations. *dvpar, pltpar* and *axispar* are psets, as has been previously mentioned.