Isaac Newton Group of Telescopes

William Herschel Telescope

WHT Prime Focus and Auxiliary Port Imaging Manual

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Contents

List of Figures

List of Tables

Part I

Introduction

This manual is intended for observers, support astronomers, and telescope operators who are using or supporting the William Herschel Telescope (WHT) for direct imaging observations with CCD detectors. The WHT provides five instruments which are capable of taking direct images, these are:-

- The Prime Focus Imaging Platform (PFIP), which can take images at the f/2.8 corrected prime focus of the WHT.
- The Auxiliary Port of the Cassegrain A&G box, which can take images at the f/11 Cassegrain focus, via a 45° flat mirror in the A&G box.
- The Taurus Fabry-Perot interferometer, which without its etalons acts as a focal reducer with interchangable f/2.11 and f/3.96 cameras, which can be used for direct imaging at those focal ratios.

- The LDSS low dispersion spectrograph, which without its grisms and masks acts as a focal reducer with an f/2.0 camera, and can take direct images. This arrangement is usually used to provide data for making the masks for LDSS spectroscopic observations.

- The ISIS double-beam spectrograph, in which either of the gratings can be replaced by a flat mirror, allowing direct imaging at the f/3.33 focal ratio of the ISIS cameras. This arrangement is used primarily for imaging polarimetry.

Imaging applications with Taurus, LDSS and ISIS are described in the respective manuals for those instruments. This manual is for users of Prime and Cass Auxiliary focii.

1 WHT Prime Focus

1.1 Prime Focus Optics

The 4.2 metre William Herschel Telescope is provided with a four-element field corrector. Two of the elements are doublet prisms, and these can be rotated to provide atmospheric dispersion correction. It is not possible to use the field corrector without the atmospheric dispersion compensator, although the elements of the atmospheric dispersion compensator can be rotated to their neutral position. The field corrector is specified to give an unvignetted field of view 40 arcmin in diameter, and the image quality over the wavelength range 4000 to 10000 Å is illustrated by the spot diagrams shown in Figure 1.

Atmospheric dispersion compensation is provided by two prisms, each consisting of two glass elements, which are rotated by equal and opposite amounts under computer control, to give compensation appropriate to the zenith distance of the field centre. The atmospheric dispersion compensator is specified to compensate for atmospheric dispersion over a wavelength range 3300 to 11000 Å, at zenith distances up to 73°. The mechanical layout of the corrector elements is shown in Figure 2.

The focal length of the corrected WHT prime focus is 11739 mm and the plate scale is 17.57 arcsec mm^{-1}. As with any refractive system there is a radial distortion which takes the form:-

$$r_{true} = k_1 r_{fp} + k_2 r_{fp}^3$$

where r_{true} is the distance of an object from the optical axis, as measured on the sky (in arcseconds), and r_{fp} is its distance from the optical axis in mm. For the prime focus corrector $k_1 = 17.57$ arcsec mm^{-1}; $k_2 = -4.12\times10^{-5}$ arcsec mm^{-3}. There is no evidence for any non-radial distortion terms, and the distortion does not seem to depend on telescope position.

1.2 The Prime Focus Rotator

With an alt-az telescope the field rotates as the telescope tracks, and the instrument is rotated to compensate for this by a two motor instrument rotator with integral cable wrap. Unlike the Cassegrain rotator the Prime Focus rotator only has a travel of 358°. This means that it is not possible to observe at certain position angles, and that extreme care must be taken when starting an exposure that the turntable will not run into a software limit before the exposure ends. Users are recommended to: **(A)** use Chris Mayer's PLANETS program, which will tell you if and when a given source will reach a wrap limit. PLANETS is an Xwindows application that runs under VMS and Motif, and is useful also to see if and for how long a planet or other source is visible from a particular observing site. **(B)** check on the TCS display to see the time to reach wrap limits.

1.3 The Prime Focus Instrument Platform

The Prime Focus Instrument Platform (PFIP) is designed primarily to allow direct CCD imaging at prime focus. Facilities provided are:-

- A seven position filter wheel, each position being able to accomodate filters up to 125mm in diameter. This filter wheel can be driven remotely under computer control to change filters. The filters are held in cells which are attached to the periphery of the wheel mechanism by a 4 mm allen screw. There is a facility for reading a barcode on the filter cell, to allow automatic detection of which filter is in the beam. The filter wheel is shown in Figure 3.
- A standard CCD Autoguider head and its Peltier cooling mechanism.
- A guide probe containing a 45° pickoff prism, a transfer lens, and a flexible fibre light guide. The output end of the fibre light guide is reimaged onto the CCD autoguider by a further transfer lens. The focus adjustment of the output end of the fibre onto the autoguider

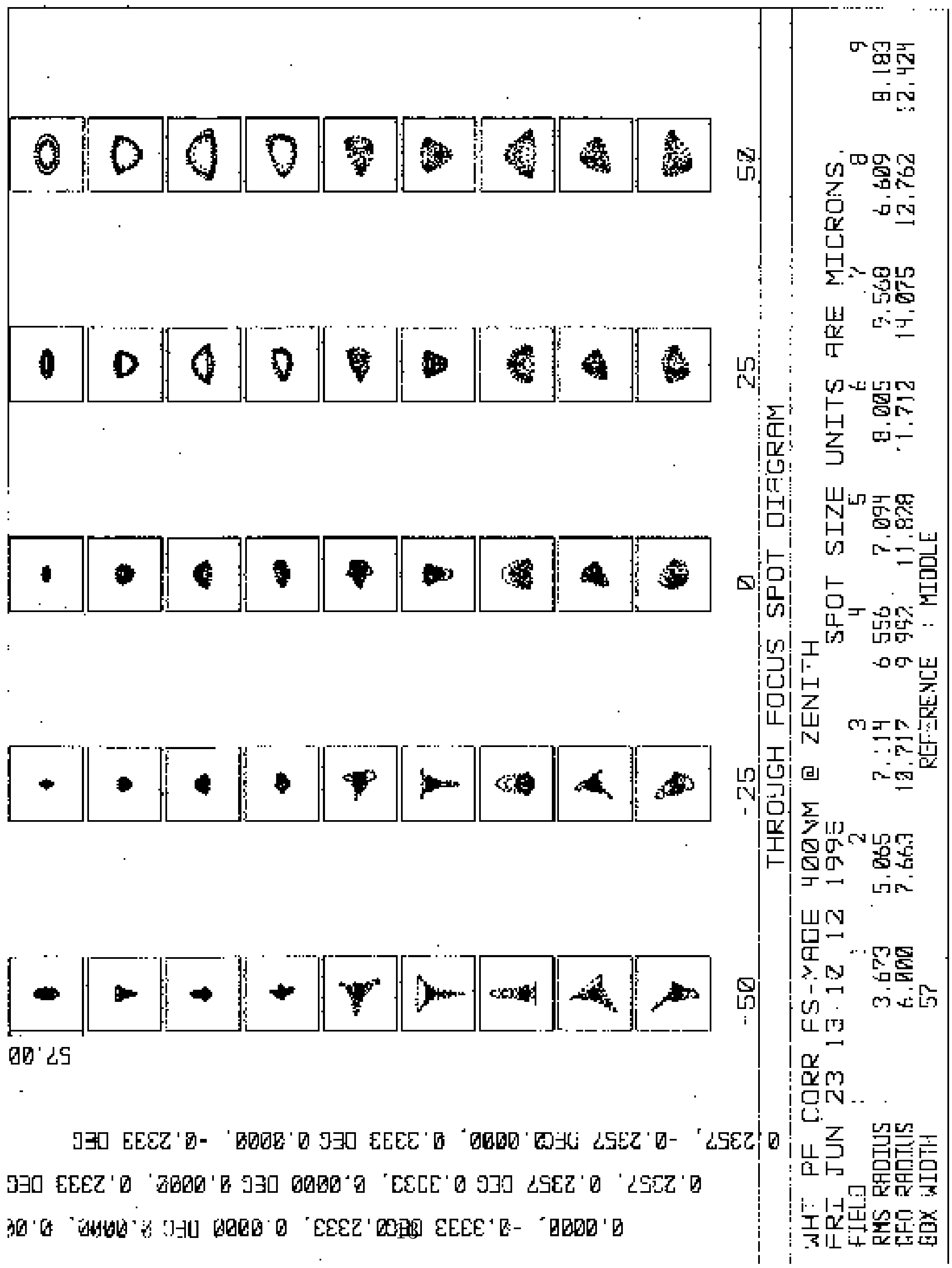


Figure 1: Spot diagrams for the corrected WHT Prime Focus,Fig1a. In Figs. 1a–1d, the 9 rows correspond to different places in the Prime Focus Field, reading from top to bottom (numbers in arcsec): on axis (0,0), (0,14),(0,−14),(+14,0),(+20,0),(0,+20),(0−20),(14.14,14.14),(14.14,−14.14). In Figs 1a and 1b, each box is 1 arcsec square. In Figs. 1a and 1b, each of the 5 columns corresponds to a different focus setting (numbers in microns): −50, −25, 0 (in focus), +25, +50. Fig1a is for a wavelength of 400nm, and is at the zenith.

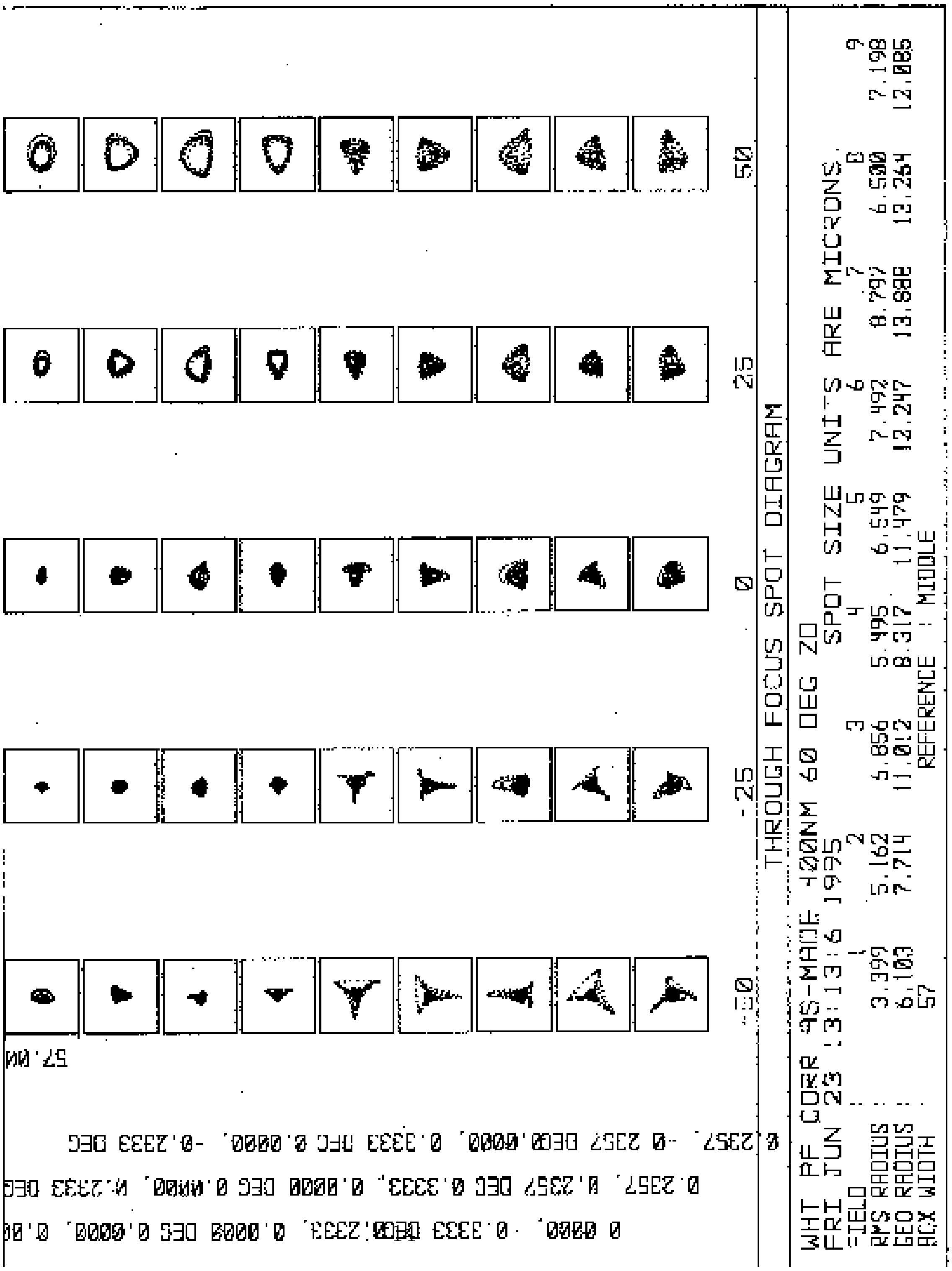


Figure 1: Spot diagrams for the corrected WHT Prime Focus (Contd), Fig1b. Same as for Fig1a, except at 60 deg Zenith Distance.

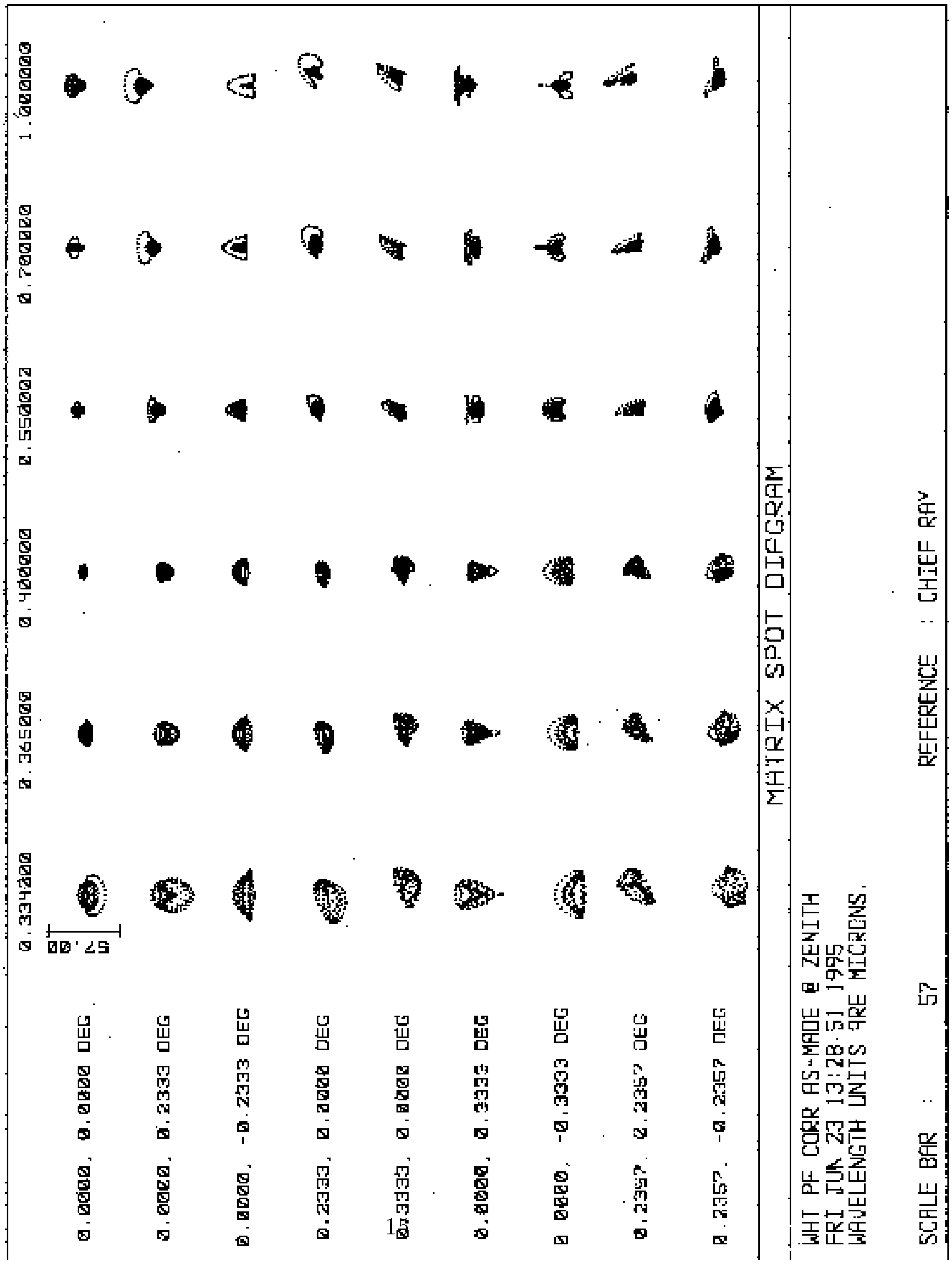


Figure 1: Spot diagrams for the corrected WHT Prime Focus (Contd), Fig 1c. Each of the 9 rows corresponds to the same field position as in Figs. 1a and 1b, but now each of the 6 columns corresponds to the following wavelengths, reading left to right: 334, 365, 400, 550, 700, and 1000 nm. Each spot is for the in-focus position. Scale the same as for Figs 1a and 1b. Fig 1c is at the zenith.

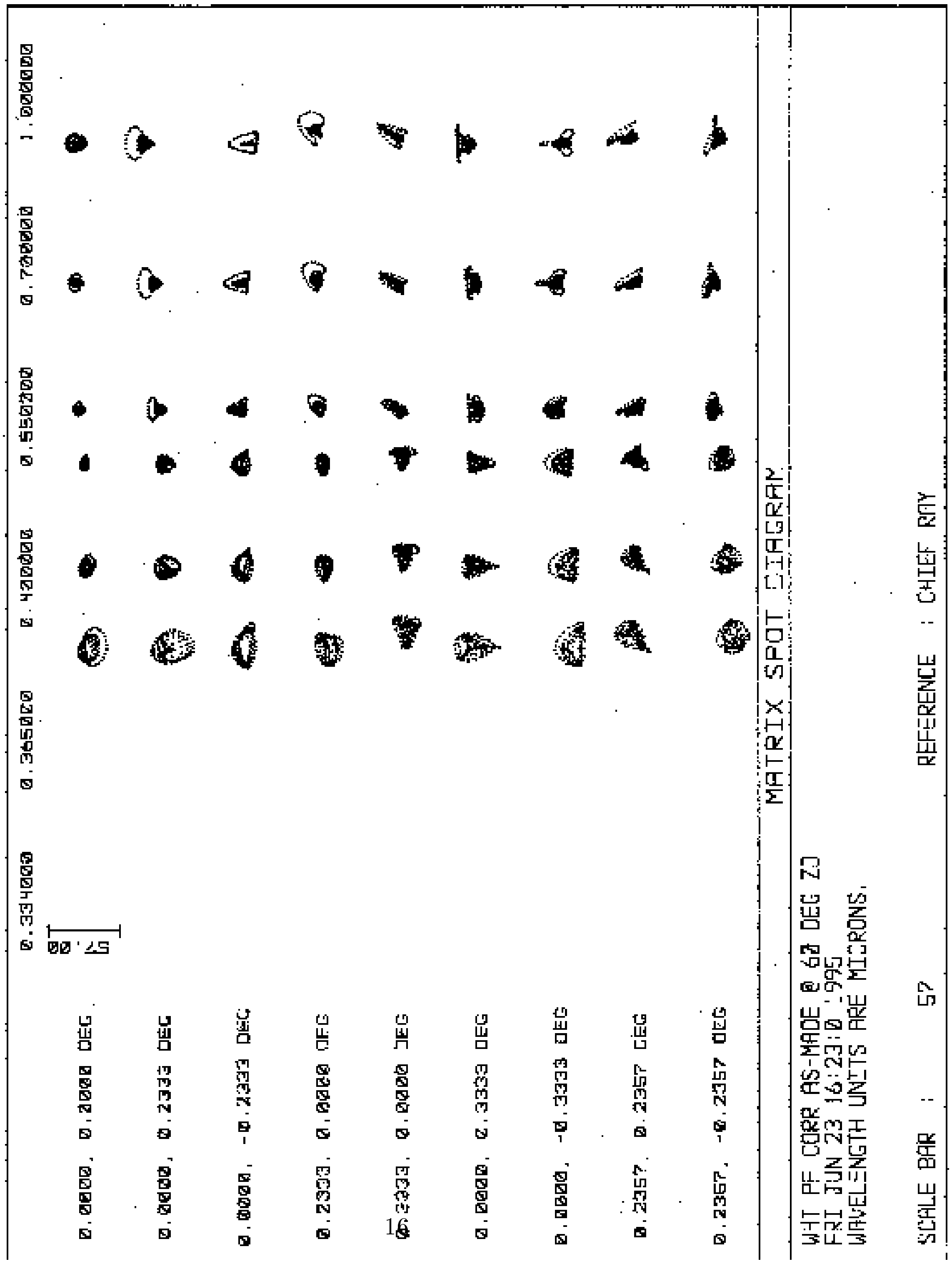


Figure 1: Same as for Fig. 1c, except at 60 deg Zenith Distance.

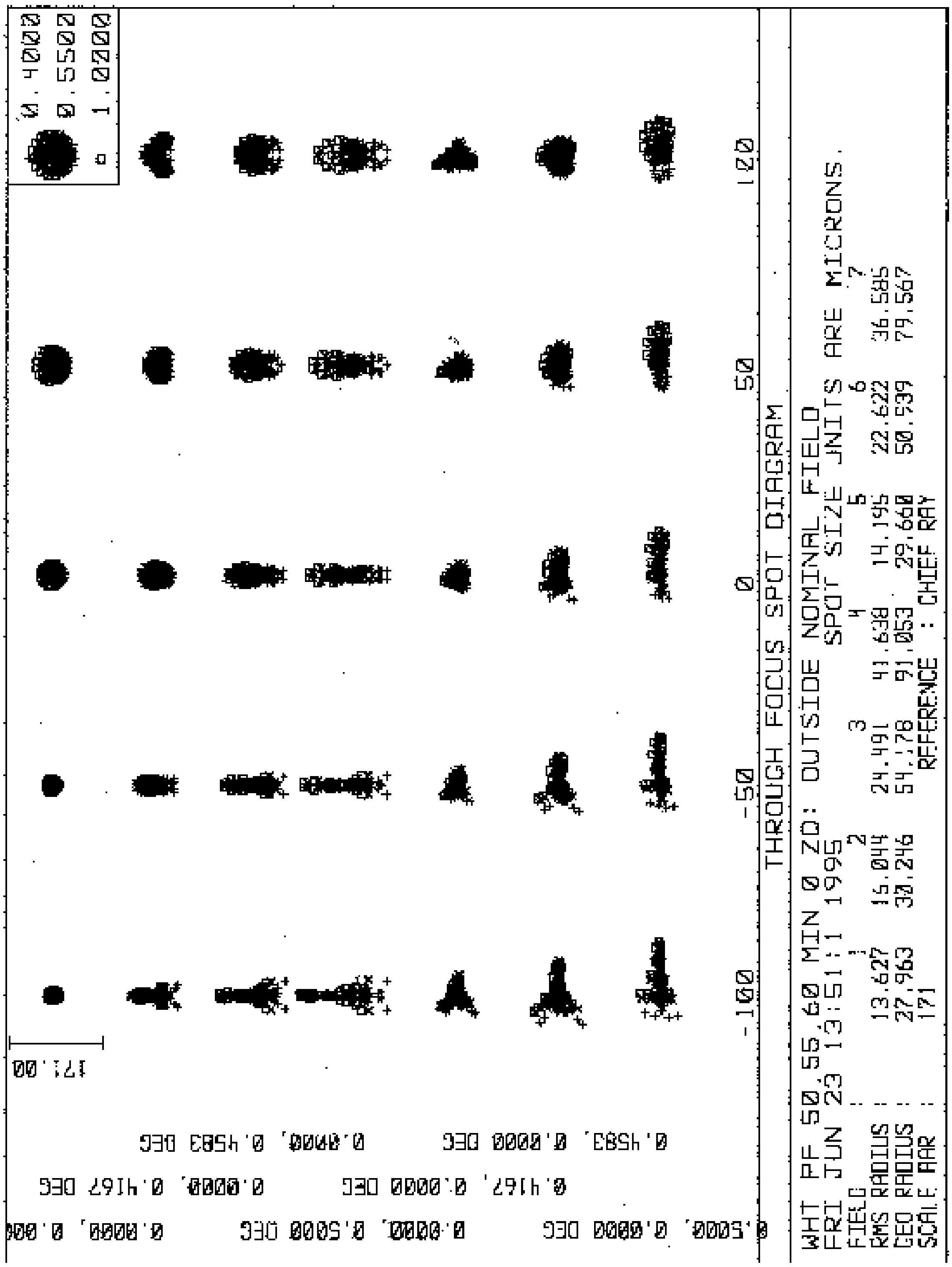


Figure 1: Similar to Figs 1a and 1b, except each of the 7 rows corresponds to these field positions, from top to bottom: (0,0) (on axis), (0,+25), (0,+27.5), (0, +30), (+25,0), (+27.5,0), (+30,0). Each of the 5 columns corresponds to the following focus positions, from left to right: −100, −50, 0 (in focus), +50, +100 microns. Each spot is the composite for light from 400-1000 nm, and Fig. 1e is taken at the zenith. The scale is shown in the upper left (3 arcsec/inch).

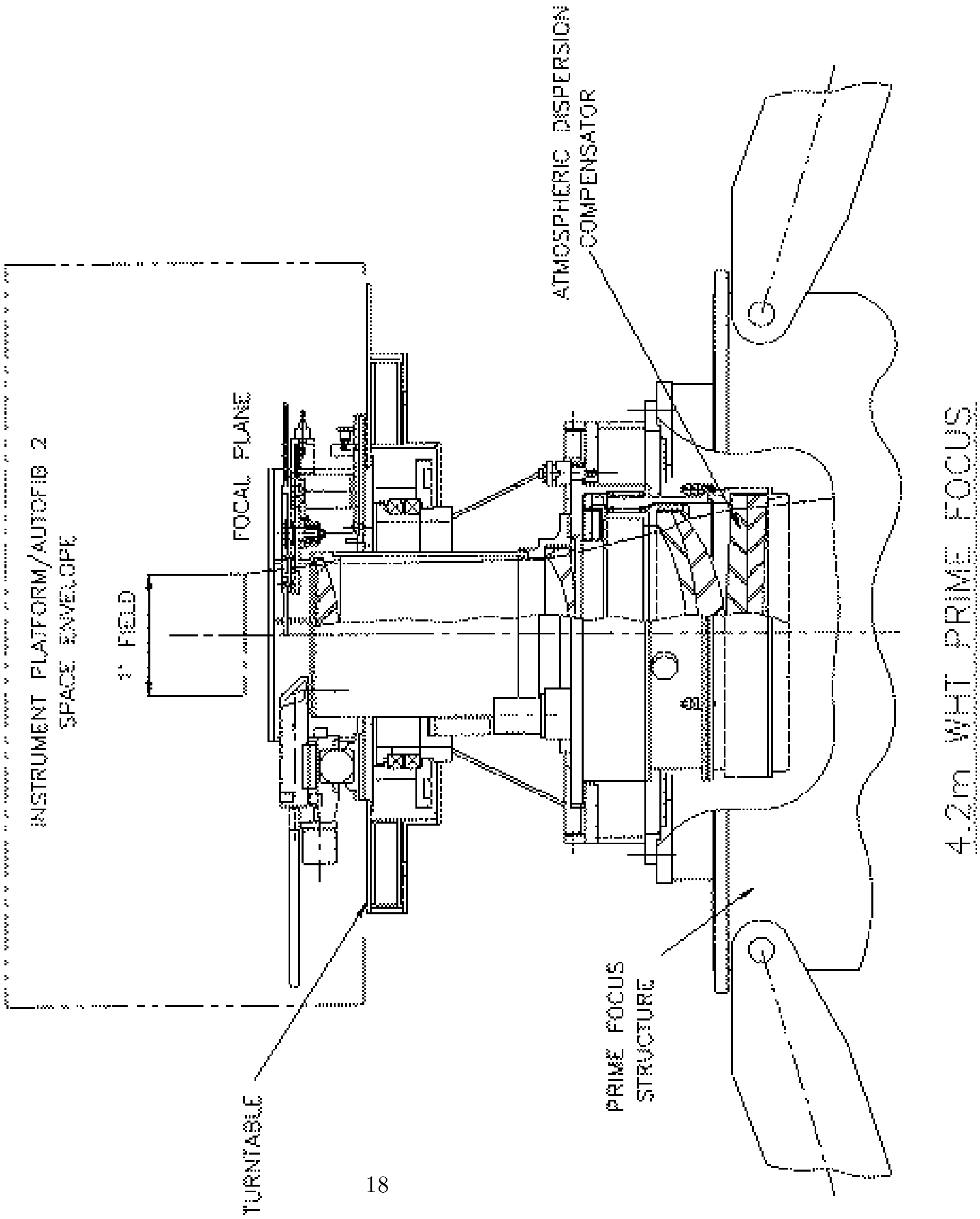


Figure 2: Layout of the WHT Prime Focus field and Atmospheric Dispersion Correctors

Table 1: CCD pixel and field sizes at the prime focus

CCD	Pixel size (arcsec)	Field size (arcmin)
EEV P88300	0.395	8.2×7.6
Tek 1024	0.421	7.2×7.2

is manual, and should be set correctly by technical staff and then not adjusted. The input end of the fibre and its transfer lens can be moved under computer control to effect focus adjustments; the guide star image must be correctly focussed onto the input end of the fibre bundle.

- A remotely operated six position filter wheel between the output end of the fibre bundle and the CCD autoguider. This filter wheel normally carries colour filters.

- A remotely driven, precisely encoded X-Y carriage which carries the guide probe. The carriage lies to one side of the optical axis, and has a travel of 110mm in the X direction (tangential at the centre of its travel) and 20mm in the Y direction (radial in the centre of the X travel. The field covered by the autoguider is 32 x 5.9 arcmin, although the field of view at any one time is limited by the size of the coherent bundle to 25 arcsec square. The autoguider field is almost entirely in the partially vignetted region of the corrector field, although the vignetting does not exceed 45%. Because of the vignetting, when selecting guide stars it is advisible to choose stars which give as high a value of the autoguider probe Y co-ordinate as possible, and as near a value of X to the centre of the range as possible.

The layout of the Prime Focus Instrument Platform is shown in Figure 2.

EEV P88300 and Tek 1024 CCDs are offered at prime focus, and the field and pixel sizes that they give are listed in Table 1.

1.4 Control Electronics

PFIP is controlled by a 4ms microprocessor controller mounted on the outer top end ring of the WHT. The 4ms is a FORTH based system, which is attached to the WHT utility network, and accepts and sends messages over

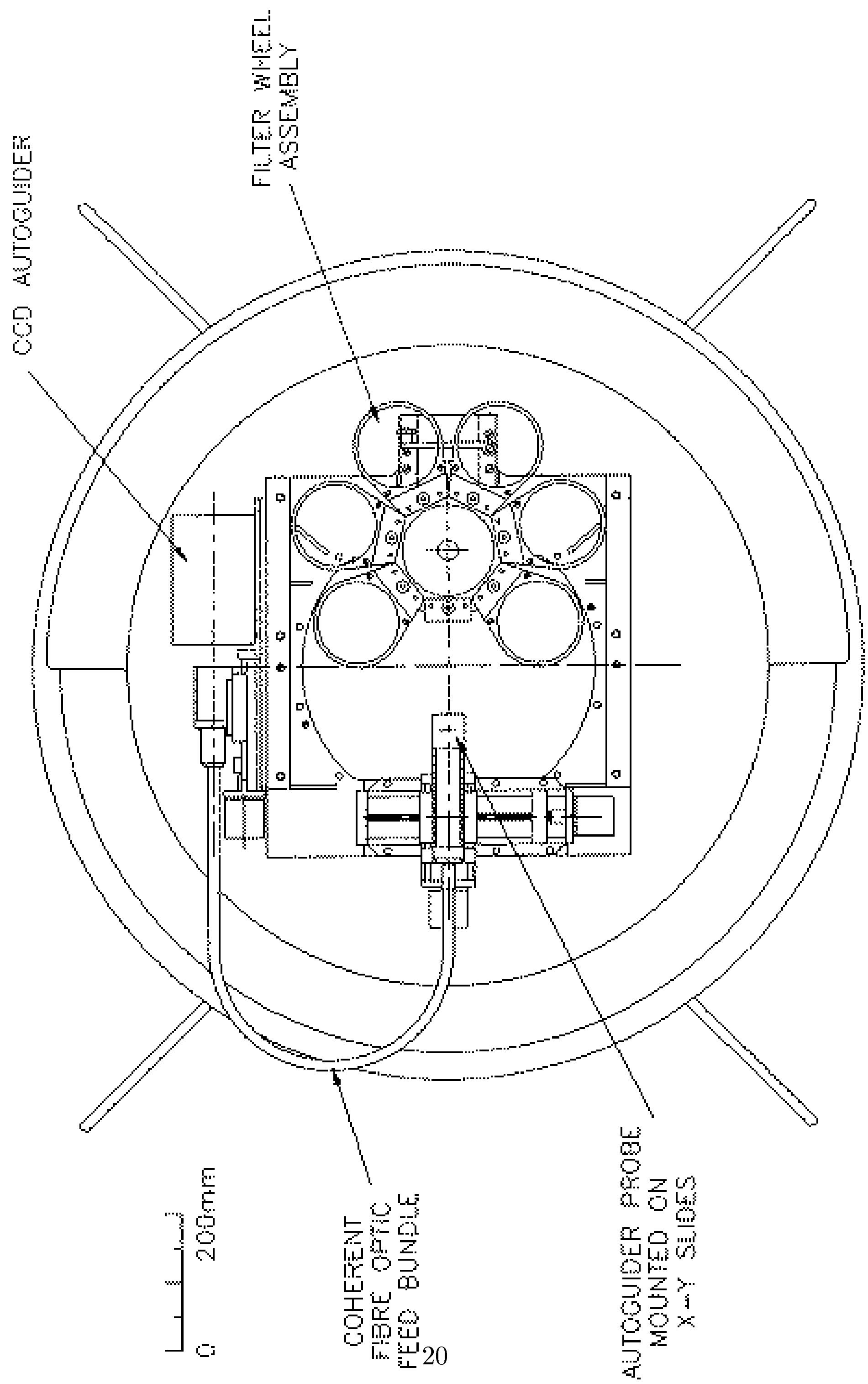


Figure 3: Plan view of the WHT Prime Focus Main Filter Wheel

the utility network conforming to the local standard protocol. The 4ms in turn controls two Local Instrument Motor Positioning Interface Terminals (LIMPITS), one of which controls the stepper motors and barcode reader of the PFIP, and the other of which controls the mechanisms of the atmospheric dispersion compensator. The Limpits replace the Stepper Motor Drive Modules (SMDMs) found in earlier instruments (such as the Cassegrain instruments).

1.5 Autoguider

The prime focus autoguider is a Peltier cooled frame transfer CCD, similar to the units at the Cassegrain and UES focii; see Section 2.2 for more details. The CCD must be flushed with Nitrogen when the cooler is in operation to prevent the formation of condensation and ice crystals on the CCD surface. If this is not done the CCD could be badly damaged. There is an automatic sensor to detect loss of nitrogen flow, but if in any doubt the user should bring the telescope to access park and check the flowmeter on the PFIP instrument platform.

The limiting magnitude of the autoguider, for guiding at 1 Hz, is V=15–17, depending on the seeing and sky brightness. Guide stars (down to V $\sim$ 14.5) can be found automatically using the ICL GSSEARCH procedure, which searches the on-line HST Guide Star Catalogue for the brightest star in the autoguider field, and moves the guide probe to that position (see Section 4.6 for more details). When the autoguider is guiding successfully, the observer or TO then "closes the loop" by telling the autoguider to send its errors to the telescope control system. When the telescope is servoing on these errors, the telescope tracking errors are reduced to the 0.1 arcsec level.

The prime focus autoguider is provided with a filter wheel with six filter positions. The available filters are: CLEAR (UBK7), EMPTY (no filter; different focus), OPAQUE (blanking disk), B (BG 28), V (BG 38), and I (RG 630). These filters do not give a standard photometric system and the Johnson letters are provided for guidance only. The autoguider can be focussed independently with the PGDFOC command to compensate for different filter thicknesses. The PSETGDFOC command may be used to do this focussing automatically, once the autoguider filter names and focus offsets have been set up using the PCHANGE command (see Section 6.1 for more information).

2 Auxiliary Focus Imaging

The Auxiliary focus is a facility provided in the Cassegrain A&G box to allow a direct image to be taken on-axis at the Cassegrain focus, at the expense of an extra (45°) reflection. The original idea of the system was that it could be used for short direct images of objects which were part of a mainly spectroscopic programme, but it has emerged as the major instrument for a number of projects for which the high throughput in the ultraviolet provided by an all-reflecting optical system, or the 0.1 arcsec pixel size, are a particular advantage. The image quality at Cassegrain is illustrated by Figure 4 which shows spot diagrams for this focus.

2.1 The Cassegrain A & G Box

The layout of the A&G unit is shown in Figure 5. It is described in some detail by P.A. Ellis in *ING La Palma Technical Note no. 56.* The unit provides acquisition, guiding and calibration facilities for all Cassegrain instruments. In the upper half of the A&G box a series of 45 degree mirrors direct light to the various ports around the circumference of the A&G box. Three of these are relevant for imaging.

- The large feed mirror, which directs the entire 15 arcmin diameter field of the A&G box to the Auxiliary port. This mirror is usually used when fibre optic aperture plates are mounted at the auxiliary focus.
- The small feed mirror, which directs the central 4 arcmin diameter region of the Cassegrain field to the Auxiliary port, leaving the periphery available for the autoguider. This mirror is normally used for CCD imaging.
- The acquisition and comparison mirror, which can direct the central part of the field to the Westinghouse ISEC TV camera for object acquisition. When used direct this provides a 1.5 arcmin field at 4.51 arcsec mm^{-1}. It is possible to insert a focal reducer which provides a field of 4 arcmin at a scale of 12 arcsec mm^{-1}. The TV camera is provided with a filter wheel with six filter positions, normally loaded with CLEAR (UBK7), B (BG28), V (BG38),

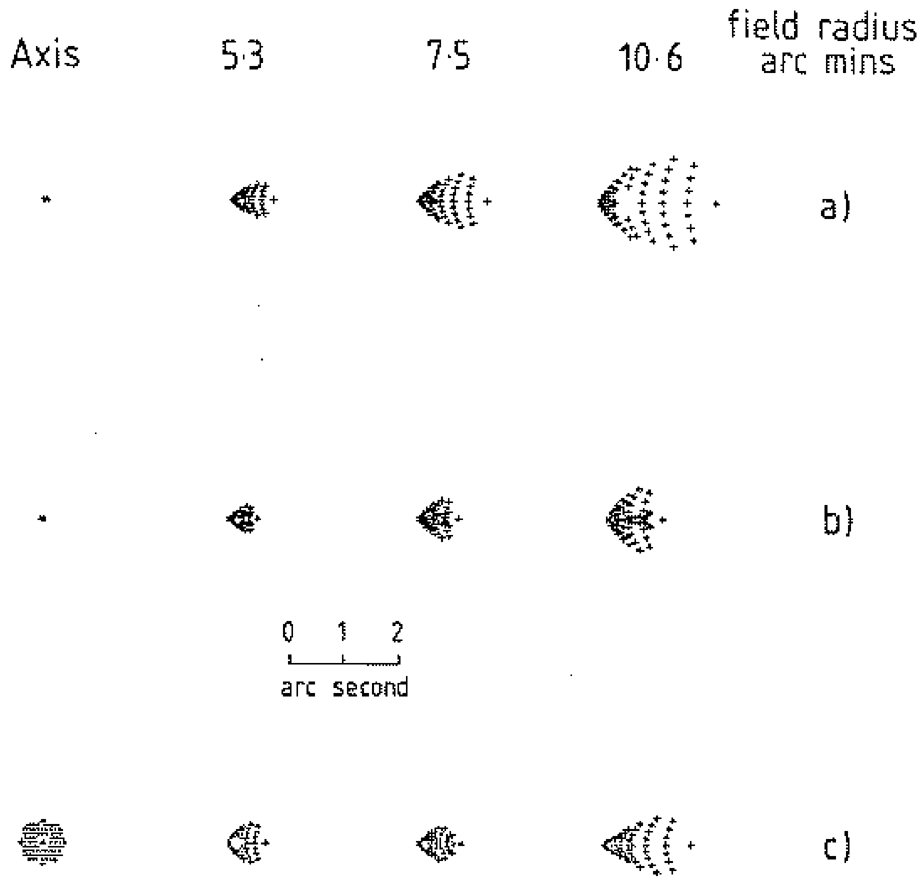


Figure 2.4: Spot diagrams for the f/11 Cassegrain and Nasmyth foci of the WHT. (a) Aberrations on a flat focal surface passing though the nominal focus on-axis. (b) Aberrations on a concave surface with radius of curvature 2.2 m. This illustrates the image quality available at the edge of the field for a suitably focused autoguider. (c) Aberrations on a flat surface which is focused for a compromise over the field.

23 31

Figure 4: Spot diagrams for the WHT Cassegrain Focus

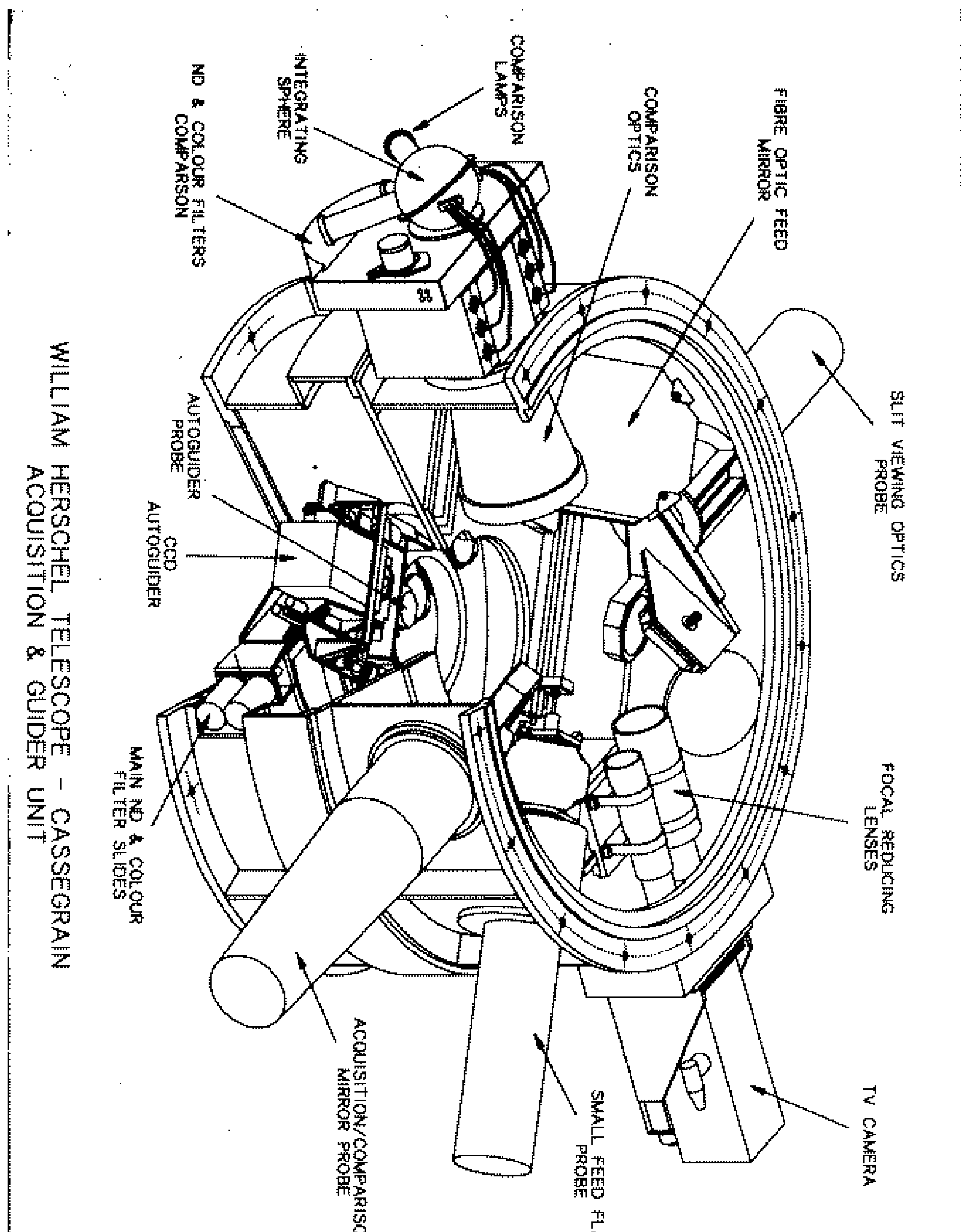


Figure 5: Cutaway view of the Cassegrain A&G box

2.2 Autoguider

The CCD Autoguider is described in detail in: *WHT-AUTO-2: Autoguider User Manual* by A.B. Gentles, and is similar to the one at Prime Focus; see Section 1.5 for more details. The autoguider consists of a CCD detector head fed by a right-angled prism and focal reducing optical system, with a field diameter of 1.8 arcmin. The autoguider utilises the off-axis field. The centre of the autoguider field rotates about the centre of the main field at a radius of 110 to 150 mm (8.2 to 11.2 arcmin) and the entire probe assembly has a radial displacement of 40 mm. The extreme edge of the autoguider field is partially vignetted, but only by about 5%. The autoguider has an azimuthal scan of 180 degrees, so the total area scanned at a field scale of 4.51 arcsec mm^{-1} equals 152 square arcmin or 0.04 square degrees. This gives a good chance of finding a star brighter than 11th magnitude at the galactic equator or 13th magnitude at the galactic pole (C.W.Allen,*Astrophysical Quantities, publ. Athlone Press, 1976*).

The autoguider head is mounted inside the Cassegrain A&G box, and contains a frame-transfer CCD having 385 by 288 active pixels, with 22 μm pixels, with a peak quantum efficiency of 50% at 7500Å. This is mounted on a copper block connected to a two stage Peltier thermo-electric cooler. This cools the CCD to around -35°C to reduce the dark current. The CCD must be flushed with Nitrogen when the cooler is in operation to prevent the formation of condensation and ice crystals on the CCD surface. If this is not done the CCD could be badly damaged. There is a flowmeter on the nitrogen outlet line from the CCD Autoguider, the user should check that nitrogen is flowing through this as soon as the CCD begins cooling.

The limiting magnitude of the autoguider, for guiding at 1 Hz, is about V=17.5 in good conditions (i.e. 1-arcsec seeing and a dark sky). The ICL GSSEARCH procedure may be used to automatically find guide stars (see Sections 1.5 and 4.6 for more details). The available filters for the Auxiliary Focus autoguider are the same (??) as for that at prime focus: CLEAR, EMPTY, OPAQUE, B, V, and I. The AUTOFOCUS command is used to set the Auxiliary Focus autoguider focus (see Section 6.2).

2.3 The Auxiliary Focus Filter Unit

The Auxiliary focus filter unit is a blue box mounted on at the Auxiliary port, which contains a 6 position filter wheel similar to the INT and JKT filter wheels. The maximum size of the filters to fit in this wheel is 51mm

Table 2: CCD pixel and field sizes at the Auxiliary port

CCD	Pixel size (arcsec)	Field size (arcmin)
GEC P8603	0.10	0.95×0.63
EEV P88300	0.10	2.1×1.9
Tek 1024	0.11	1.8×1.8

square or 55mm diameter. Adaptors for smaller filters can be made if requested well in advance. The filter unit also contains a CCD shutter 25mm in diameter, which is operated as normal by the CCD controllers. The filter wheel is controlled by the Cassegrain A&G box 4ms microprocessor.

At the f/11 Cassegrain focus, the telescope scale is 4.51 arcsec mm^{-1} at the detector, which gives a scale of 0.10 arcsecs per 22 μm CCD pixel. At present GEC P8603, EEV P88300 and Tek 1024 square CCDs are offered at the Auxiliary focus; Table 2 summarises the pixel and field sizes given by these CCDs.

The unvignetted field at the Auxiliary port is currently limited by the shutter to 2.0 arcmin diameter, thus the final unvignetted field is the intersection of this circle with the rectangle given in the table.

Part II

CCD Detectors

CCDs are widely used in astronomy, and are the major detectors for almost all of the instruments of the Isaac Newton Group. Descriptions of CCDs and their operation at a non-technical level are given in a number of astronomical publications; two recent reviews have been given by C.D. Mackay in *Annual Reviews of Astronomy and Astrophysics*, volume 24, page 255; and by P.R. Jorden in *Modern Technology and its Influence on Astronomy*, edited by J.V. Wall and A. Boksenberg, published by Cambridge University Press, page 271, 1990. A good introduction to the use of CCDs is also given by P.R. Jorden in *ING La Palma Technical Note No. 93 (January 1994)*. The IRAF (Image Reduction and Analysis Facility) package is widely used for the processing and analysis of CCD data; documentation is available by anonymous ftp (iraf.noao.edu; see the iraf/docs directory and ccdguide.ps.Z in particular) and may also be found in binders in the WHT control room. The entire Starlink software collection, including the FIGARO package, is also available on all machines.

2.4 Schematic view of the CCD systems

The CCD systems in use at the WHT are described by P.R. Jorden *et al.* in *ING Tech Notes 92 (Nov. 1993) and 93 (Jan. 1994)*. In brief the CCD systems consist of the following components, ordered approximately by the data path from detector to user.

- CCD chips contained in Oxford Instruments cryostats (the cryostats are painted bright red). New chips and types of chips are frequently brought into use, but at the time of writing the main chips in use at the WHT are GEC P8603, EEV P88300 and Tek 1024. The properties of these, and the next generation of CCD chips (the EEV P88500) are tabulated below. New types of chips will be announced in *Gemini* as they become available. The Oxford Instruments cryostats contain liquid nitrogen, and the CCDs are mounted on a heated copper block. By controlling the current into the heating elements, and by sensing the chip temperature with a platinum resistor, it is possible to maintain the CCD temperature at a preset value to an accuracy of about 0.1°C. The value of this preset temperature depends upon the CCD, and typical values for the CCD types are listed in Table 3 below.
- A preamplifier box, usually painted blue, which is mounted on the side of the cryostat.
- The compact CCD controller, designed by NFRA Dwingeloo, and described in detail by J.D. Bregman and A. Doorduin in *Proc. S.P.I.E., volume 627, page 616 (1986)*, and by J.D. Bregman and N.R. Waltham in *Proceedings of the ESO-OHP workshop on The Optimisation of the use of CCD Detectors in Astronomy, p127 (1986)*, and which is mounted in one of the electronics racks on the Cassegrain cable wrap. The compact controller contains the following components:-
  - A low heat dissipation power supply.
  - A CPU card containing an MC68008 microprocessor running a PROM based FORTH system.

  - A Temperature, shutter, and preflash control card for each CCD head controlled by the controller.
  - Cards which provide and sequence the clock and bias voltages for each CCD.
  - An analogue to digital converter card containing a 16 bit analogue to digital converter.
  - A Correlated Double Sampler (CDS) board.
  - A fibre optic transmitter and multiplex control card.
  - A floppy disc controller for FORTH software development.
  - A real time board with opto-isolated RS232 ports for communication with the Utility Network and with terminals.

- A fibre optic cable run, with a number of connectors, passing through the cassegrain cable wrap. The fibre optic cables usually have a bright yellow (Cassegrain) or orange (prime) sheath.

- The Fibre Optic Multiplexer (FOX) unit, containing the CCD Interface sequencer and one CCD interface card for each controller, in the upper rack of the Detector Memory System cabinet in the control room. The CCD interface card includes a fibre optic receiver, which decodes the serial data from the optical fibre, and a 512 by 24 bit FIFO buffer into which the data is placed in parallel form. The Interface Sequencer card is responsible for reading data from the CCD interface cards into the DICI card (see below). There can be up to 16 individual CCD interface cards in the rack, although there are not usually more than three. Each pixel, when read from the CCD interface card FIFO, has 24 bits, of which 16 are data bits, and 7 are address bits, which ensure that the data arrive in the correct buffer in the Detector Memory System. The CCD interface card has three lights on the front. These are:-

  - *Data Available*, a green light which indicates that data are available in the FIFO, and the CCD controller is sending data.
  - *FIFO Full*, a yellow light which indicates that at some point the FIFO has been filled, and CCD data have probably been lost.
  - *G.O.A.T*, a red light which indicates that CCD Interface card cannot detect the carrier for the optical signal.

Table 3: CCD types available at the WHT (as of May 1993)

CCD Type	Pixel (μm)	CCD Format (pixels)	Image Format (pixels)	Read noise (e^-) normal	(quick)	Dark Current e^-/hour	Operating Temp °K
EEV P88300	22.5	1242×1152	1280×1180	3–4	5	3–10	140-150
EEV P88500	22.5	2172×1152	2200×1180				140-150
GEC P8603	22.0	576×380	590×400	6–10			150
Tek 1024	24.0	1024×1024	1124×1124	5	6	<10	183

If either the yellow or red lights are showing on the relevant CCD interface card then there is a problem.

- The Dual IPCS CCD Interface (DICI) card in the DMS rack.
- The Detector Memory System. This is described in brief in the next chapter.

2.5 CCD chips in current use at the WHT

Table 3 summarises the characteristics of the types of CCD chips in current use for all instruments at the WHT. Availability of CCDs changes frequently, and updates to this information will be published regularly in Gemini. At the time of writing the CCDs available are: EEV3 and EEV6 which are EEV P88300s; TEK1 and TEK2 which are Tektronix 1024 square CCD; and GEC5 which is a GEC P8603. In the very near future EEV8, an EEV P88500 will become available. See Figure 6 for the quantum efficiency curves for the TEK2 chip and a typical EEV chip.

There is a choice of five readout speeds for the CCDs, known as *"Slow"*, *"Standard"*, *"Quick"*, *"Turbo"*, and *"Nonastro"*. It is possible to select all modes from the ICL interface with the commands `SLOW`,`STANDARD`, `QUICK`, `TURBO`, and `NONASTRO` respectively. The advantages of faster speeds are a faster readout (less overhead), and a higher dynamic range. The disadvantage is a higher readout noise. *Note that the bias (overscan) level also changes with readout speed.* For each CCD there is a distinct value of the "gain"; the conversion factor between the output of the analogue to digital converter and the number of detected photoelectrons per pixel, for each readout speed. The values of "gain", usually expressed in e^-/adu, will be known to local staff. Table 4 lists the changes in CCD characteristics with

Table 4: Gain and noise as a function of readout time for the TEK2 CCD (as of 28/7/94)

Readout Speed	Chip readout time (s)	Gain e^-/adu	Readout Noise e^-	Linear to (adu)	Bias Level (adu)
SLOW	117	1.1	3.9	60000	1004
STANDARD	75	1.2	4.4	60000	1104
QUICK	43	1.6	6.3	60000	1236
TURBO	30	2.5	9.3	50000	1170
NONASTRO	17	4.4	17.1	30000	445

changing readout speed for the TEK2 CCD. See the CCD Quality Control Manual (green binder) in the WHT Control Room for details of the various chips, e.g. linearity, gain, read-noise, read-out speed, bias levels. The CCD Quality Control information is also available on the World Wide Web (WWW) at this URL: ftp://ftp.ast.cam.ac.uk/pub/lpinfo/CCDs/. See the preceding WWW page (URL: http://www.ast.cam.ac.uk/ lpinfo/) for more general information on the ING telescopes and instruments, and the La Palma site.

For normal broadband observing the observer may require either QUICK or TURBO speeds; for most applications QUICK is recommended (note that at TURBO speed the TEK2 chip becomes nonlinear at $\sim$ 50000 ADU). For narrow band imaging where readout noise is more important and integrations are longer, STANDARD speed is recommended.

All CCDs produce an image which is larger in both dimensions than the active area of the CCD, this area is given in column 4 of Table 3. The additional image area consists of *underscan* and *overscan* and *dark reference regions*. The difference between these types of reference regions, and the location of the regions for CCD types in use on the WHT, are discussed by P.R. Jorden in *ING La Palma Technical Note No. 93*. The bias level in each data frame, which is an electronic offset with a low frequency time dependence, is estimated most reliably from the serial underscan region, in regions of the image frame which are given in Table 5.

On-chip binning and windowing are available for any CCD, and the parameters can be controlled using the ICL commands `BIN` and `WINDOW`. On-chip binning is useful not only in reducing the amount of data read out from the CCD, and thus the dead time between exposures, but also in reducing the effective readout noise in the data. Because the readout

Table 5: Recommended bias regions for WHT CCDs

CCD Type	Recommended bias region in X pixels	Recommended bias region in Y pixels
EEV P88300	6–15	101–1000
EEV P88500	6–15	101–1000
GEC P8603	5–9	101-500
Tek 1024	11–40	101-1000

noise occurs only once for each summed pixel, the effective readout noise is reduced by a factor of the square root of the number of pixels summed. On the other hand, because the output of the analogue-to-digital converter limits the amount of charge that can be read from the CCD in any one pixel, on-chip binning reduces the maximum dynamic range that the CCD can provide by this same factor.

2.6 Overall performance of the system

Table 6 gives sensitivity values for Prime and Auxiliary focus determined from observations of standard stars taken at low airmass on photometric nights. These are expressed as the magnitude for a count rate of one photon/second in a given standard broad band. These numbers can be compared with measured count rates as determined with, for instance, the iraf routine `imexamine` running on the SPARCstation. Figure 7 shows: A) the S/N achieved in 900 sec as a function of V magnitude, and B) the time required to reach a S/N of 5 (a detection) as a function of V magnitude; the 3 curves in each Figure show the effects of varying the FWHM between 0.5 and 2.0 arcsec. These calculations assume the TEK2 chip, with a pixel scale of 0.42 arcsec/pixel and a R/N of 5 electrons, and a dark sky of V=20.8 mag/arcsec^2. For example, assuming a FWHM of 1 arcsec, a S/N of 5 at V=25 can be reached in $\sim$ 500 sec of integration. See Appendix C for more details of the La Palma sky.

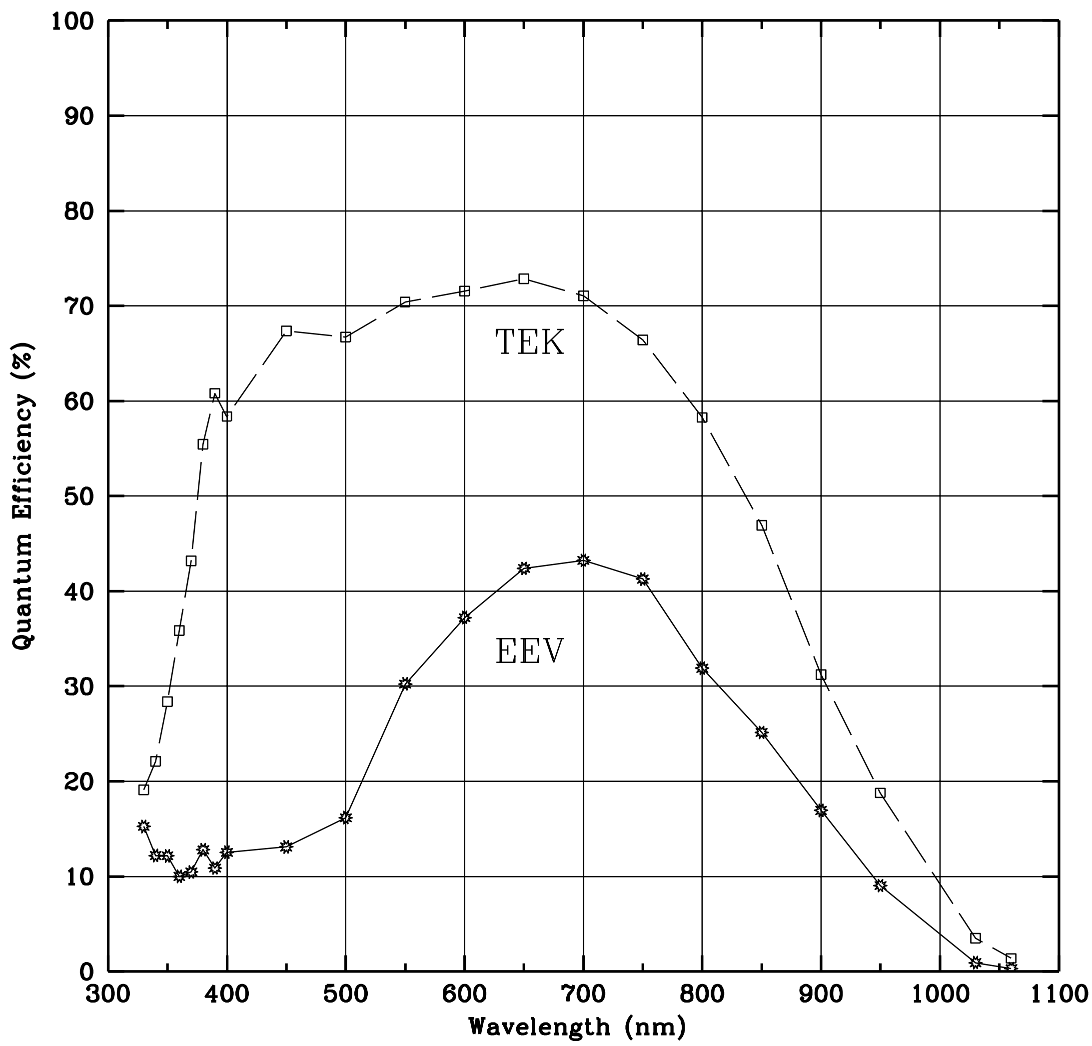


Figure 6: Quantum efficiency of WHT Imaging CCDs
[Quantum Efficiency of CCDs available for WHT imaging. The top, dashed curve corresponds to the TEK2 chip, while the lower, solid curve corresponds to the EEV chip.]

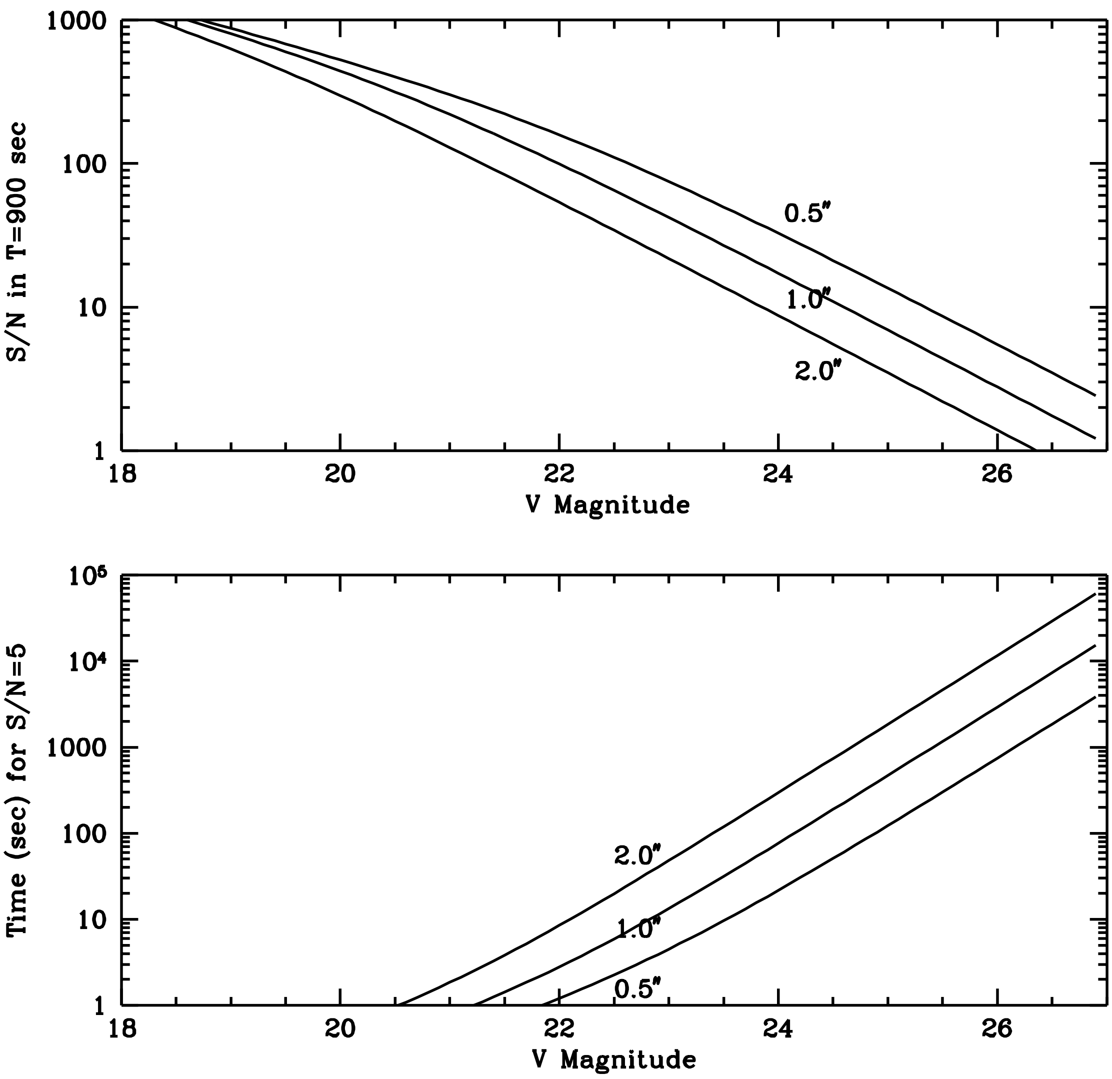


Figure 7: SN Calculations
[Signal-to-Noise calculations for WHT and TEK2 chip. Top plot shows S/N reached in a 900s exposure vs V magnitude, while bottom plot shows exposure time needed to reach S/N of 5 (a detection) vs V magnitude. The three curves in each figure correspond to FWHM values of 0.5 arcsec, 1.0 arcsec, and 2.0 arcsec, and we have assumed a read-noise of 5 e^-, an image scale of 0.42 arcsec/pixel, and a dark sky of V=20.8 mag/arcsec^2.]

Table 6: Sensitivity, expressed as broad band magnitude for 1 photon/s, of WHT prime and auxiliary imaging systems

Telescope, Focal station, CCD	Scale (arcsec/pixel)	U	B	V	R	I
WHT Prime + GEC/EEV CCD	0.395					
WHT Prime + TEK CCD	0.421	24.1	26.2	26.4	26.5	26.0
WHT F/11 (Aux) + GEC/EEV CCD	0.101		24.8		25.7	
WHT F/11 (Aux) + TEK CCD	0.108					

Part III

Computers and Operations

3 Control System

3.1 Control system overview

The main elements of the control system are shown in Fig. 8. Mechanisms are controlled by the observer typing commands at the ICL instrument control interface. The ICL interface runs on the system computer (currently a VAX 4000 called LPVF), and the display is via the Observer's VAXstation 3100 (LPVS2). ICL commands are typically procedures containing lower-level commands to d-tasks (device tasks) which are high-level (PASCAL) programs running on the system computer (LPVF) as sub–processes of the main observer's process. D-tasks for the Telescope; the acquisition and guidance system (PFIP or CAGB), the Autoguider (AUTO), the CCD in use and the DMS will be running on the system computer. The d-tasks in turn exchange messages over the utility network Ethernet with the Motorola microprocessors controlling individual stepper-drive motors, barcode readers and shutter modules. The messages are typically commands to move, status requests and status returns.

Most of the mechanisms are controlled via Motorola 6809 (locally known as '4MS') microprocessors; these control both of the acquisition and guidance systems. The TV, autoguider and Detector Memory System (DMS) each use a 68020 processor in a VME chassis (housed in the blue control cabinets). The CCD controllers (including that for the autoguider CCD) are based on 68008 microprocessors. The microprocessors are programmed in FORTH. Each of the microprocessors, and the system computer, is connected to the utility network via a Network Interface Unit (NIU). Each NIU can connect up to four microprocessors. There are currently two NIUs on the telescope and two in the control room. Data from the CCDs is transmitted via fibre-optic links to the autoguider and DMS VME systems. Data arriving at the DMS are automatically sent to the data disk on the system computer and may also be transferred to the SPARCstation (currently LPSS3). The integrating TV system is currently stand–alone and cannot be controlled across the Utility Network. If the ICL/d-task control route fails for some reason, mechanisms can often be controlled more directly from the engineering terminals in the control room, by keying in messages to be sent over the utility network. At a still-lower level, duty technicians can plug a terminal directly into a microprocessor on the telescope and send commands from there.

LPVF is linked via DECNET, running over a separate Ethernet, to the telescope-control computer (a microVAX-II, currently LPVB), to the VAXstation running the user interface, to other VAX 4000 computers on a DEC cluster, to the DECservers serving terminals and printers, and to SPARCstations on a SPARC cluster. Separate Ethernets at the INT and JKT are connected to the WHT ethernet via fibre-optic links.

The DMS and several of the VAXes and SPARCstations can be used for data reduction. The DMS provides a few simple analysis functions e.g. cuts, statistics. FIGARO and other reduction packages, including IRAF, are available on the VAX clusters on both the mountaintop and at sea level. FIGARO, IRAF and SAOIMAGE can be run on the SPARCstation on the control desk (Section 3.3) and also on the SPARC cluster in the control room.

Telescope control is effected via commands issued to the control system running on the telescope-control computer, which is interfaced to the telescope mechanisms via CAMAC. Most telescope-control commands can be issued from the ICL interface and it is intended that in the future the distinction between operator control of the telescope and observer control of the instrument will blur.

Most of the information needed by the observer about the status of the system is included in the telescope-control information display, the instrument-control MIMIC and the white-board. The MIMIC is discussed in Section 3.6 below; it displays information contained in the 'notice-boards' which are continually updated by the d-tasks as a result of the commands and status returns they receive. Ephemeral information which is not (yet) held on-line e.g. contents of filter wheels, CCD locations, is usually recorded on the whiteboard in the control room. There is some overlap between the information held on-line and that written on the whiteboard. Some useful instrumental information (e.g. focus offsets) is recorded in the telescope logbook.

3.2 The Detector Memory System

The Detector Memory System allows detector data to be collected, displayed and transferred to the system computer. A detailed description of the system is given by *Johnson 1986 (Electronics report 413, the Detector Memory System).*

The DMS is a purpose-built computer, based upon a Motorola 68020 microprocessor, with a large area of memory (128 Mbytes) for storage of detector data. The system design is based on the industry–standard VME architecture. There is a high speed data interface (DICI; Dual IPCS CCD Interface) between the detectors and the VME memory. The system also has an image display facility, based on an Opal Graphics Controller.

Immediately after each exposure the data from all detectors appears in memory in the Detector Memory System (DMS). Images obtained with CCD detectors are read out into the DMS at the end of an exposure.

The DMS is capable of handling multiple detectors simultaneously, reading the data from different detectors into different areas of memory (normally referred to as buffers). This feature is particularly important for the operation of ISIS.

3.3 The SPARCstation

Data collected by the Detector Memory System (DMS) may be saved to the SPARCstation 2 (currently LPSS3) for examination using SAOIMAGE or IRAF applications.The SPARCstation is intended to meet the need for very rapid on-line evaluation of data, using standard reduction software. The system consists of a SPARCstation 2, with 64 Mbyte of memory and 3 Gbyte of local disk storage, connected to the DMS via a commercial S-bus to VME adapter. This allows very rapid transfer of data from the DMS to the SPARCstation.

The run number of the saved data is the same as that used on the VAX, **if** the image is transferred *before* a new exposure is started (since the run number of the saved image corresponds to that of the *current* exposure).

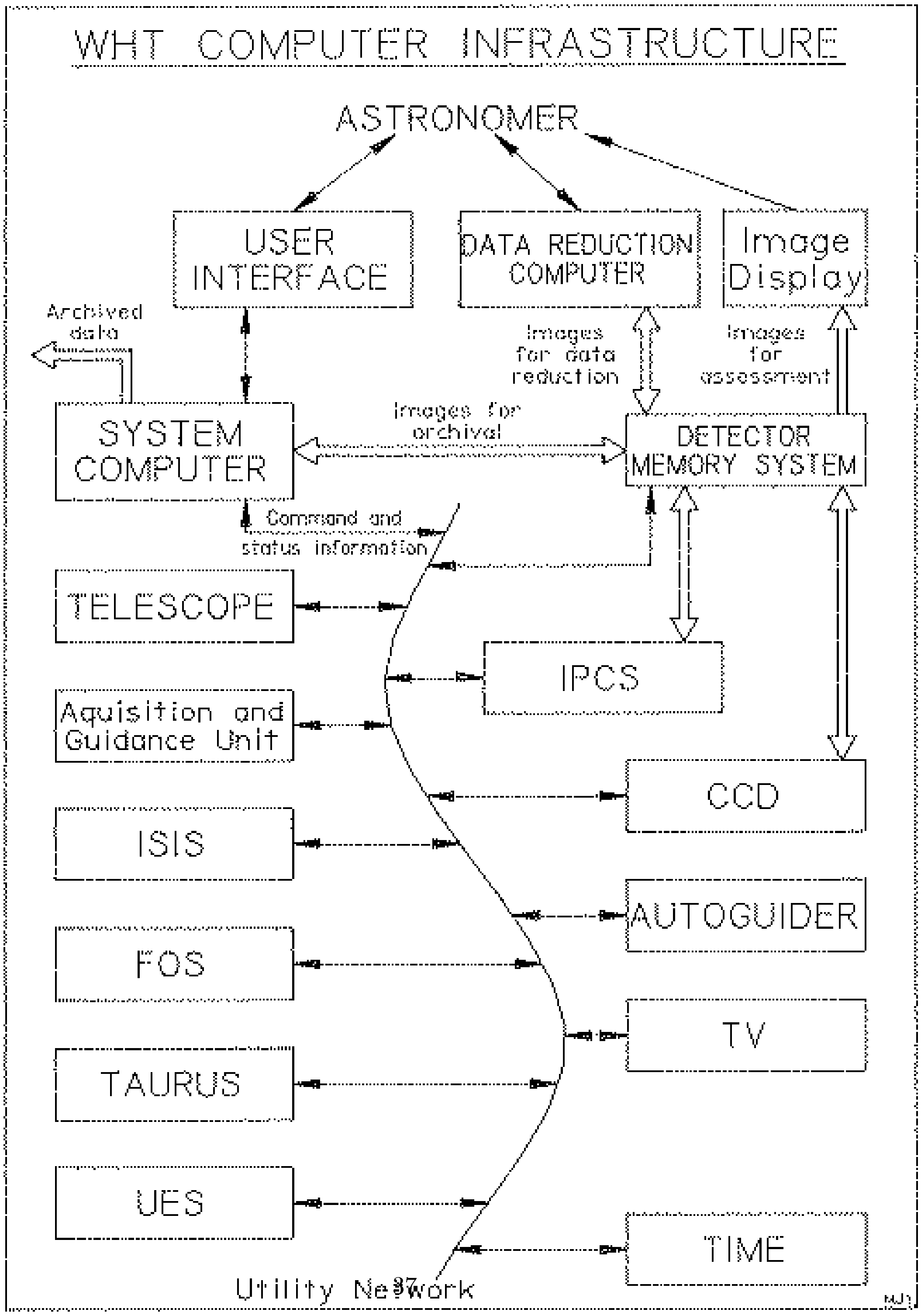


Figure 8: Schematic representation of the WHT Instrument Control System

Data may be written from the SPARC to an exabyte in TAR format, or FITS format from IRAF. Instructions on starting up the SPARC and on using the various applications are kept in the control room. Image-examination routines run much faster on the SPARC than on the VAXes.

IPCS data can be saved to the SPARC while the exposure is building up.

The windows typically open on the SPARC are:

- DMS-SPARC interface, used to save data from any of 7 DMS buffers to the SPARC, and also to obtain statistics on any of the images in the buffers (size, min, max and SD);
- SAOIMAGE, used for display and mouse-controlled examination of the image;
- IRAF command language, used for running other applications e.g. `imexamine`;
- IRAF (Tek), used for displaying line graphics;
- Console window, where UNIX error messages appear;
- DMS control

The interface for transferring data from DMS memory to the SPARCstation local disks is controlled graphically on the SPARCstation itself. To transfer a specific buffer to the SPARCstation the user simply moves the pointer to the name or number of that buffer, selects it with the mouse, then selects with the mouse the SAVE option in the interface window. An IRAF format file is then created in a scratch area on one of the SPARCstation discs, and the name of the file created is displayed in the interface window. At present no header information at all is stored with the data files for `glance` or `scratch` images, while headers are retained for `runs`. The images can then be displayed in the SAOIMAGE window with the IRAF command `display`.

IRAF contains many facilities for rapid analysis of data of all types, and users who require specialised facilities are advised to refer to the KPNO user manuals and cook-books, which are kept in dark blue loose leaved binders in the control room. For quick-look analysis of images and simple spectroscopic data the IRAF command `imexamine` has many of the required facilities. Typing `help <commandname>` at the IRAF interface produces a detailed description of the command, and typing `help <commandname> | lpr` will produce a hard copy of the help file on the SPARC laser printer.

Eventually, the DMS display functions will be transferred to the SPARC, making the DMS monitor superfluous. Header examination and FITSOUT from the SPARC should also be available. The mountain-top SPARC cluster currently includes 8 SPARCs, exabyte and DAT drives, and a laser printer. One can run IRAF, SAOIMAGE and FIGARO from all of these machines.

3.4 The Utility Network

The Utility Network is a local Ethernet, running between the various focal stations of the WHT, and the control room, over which the microprocessor systems (the 4ms systems which control the instruments and the Engineering Mimic; the VME computers which control the Autoguider, and the DMS; and the CCD controllers) communicate. Each device communicates via a Network Interface Unit (NIU), and each NIU can connect up to 4 devices to the Ethernet link. The system computer is also connected to the Utility Network via an NIU; this allows the transmission of messages from the User Interface to the devices. The Utility Network Ethernet is physically separate from the Ethernet which connects the VAXcluster and various other computers around the site. Utility Network messages conform to a local protocol set out in *Johnson 1986 (Electronics report 412, 4.2m WHT Utility Network: Instrument Control Recommendations).*

3.5 The System Computer and User Interface

The system computer has two principal roles as part of the data-acquisition system:

- The system computer, running the ADAM control system, is responsible for coordinating the entire data acquisition process. The commands for doing this are listed in Part VI.

- The data acquisition system writes the data to files on the system computer datadisk, ready to be archived.

On completion of an exposure, the data is normally transferred from the DMS to the system computer, via a DR-11W interface. The header information associated with that data will have been collected by the system computer, either during the exposure, or on completion of the exposure. Data and headers are then merged into a datafile on the system computer disk. The datafile is in HDS NDF format, the header information being stored in the standard FITS extension to this format. Finally, two copies of the data are written to tape; a FITS format tape for the La Palma archive, and either a FITS tape or a VAX backup tape for the observer.

The system computer is networked to various data reduction computers (currently a VAX 3500 plus several VAXstations). Data can be copied across to these machines for immediate processing.

3.6 The MIMIC display

The MIMIC display running on the VAXstation 3100 gives mainly-graphical representations of the current status of the telescope, instruments and detectors. There are a number of pages, which can be selected using the mouse. Current pages include:

- **CAGB:** Light path and status of mechanisms in the A&G box only.
- **PFIP:** Light path and status of mechanisms in the Prime Focus Instrument Platform, including status of the Atmospheric Dispersion Compensator.
- **PRIME:** PFIP status display as on the PFIP page plus CCD summary for the CCD currently on Prime Focus.
- **CCDs:** Focal station, chip name, size, windows, binning, temperature (and difference from nominal), readout speed, exposure status, shutter status, requested exposure time, exposed time, UT start, for each CCD.
- **CCDs SUMMARY:** Temperature, exposure times, times to go, windows for each CCD.

A small version of the CCD summary page is permanently displayed.

The current state of any mechanism or light path is identified by its represented colour
on the MIMIC screen. The colour scheme is:

WHITE	mechanism is ok although not being controlled
RED	mechanism is in error
BLUE	mechanism is moving
GREEN	mechanism is successfully being controlled
YELLOW	the current selected light–path

The following ICL commands relate to the MIMIC (they are only normally needed when problems occur):

`MIMIC PAGES`	List names of available MIMIC pages (screens)
`MIMIC UPDATE`	Refresh current screen if it seems out of date
`MIMIC_START`	Start–up. Normally done in `START-UP` in ICL
`MIMIC_STOP`	Close down. Normally done in the ICL `EXIT` command
`SCREEN`	Select a screen (*e.g.*, ISIS). Normally done with the mouse.

3.7 Generating Data Tapes

ING telescope data are recorded to disk in .SDF format, and to tape in FITS format. The preferred medium is Digital Audio Tape (DAT), the second choice is Exabyte tape. It is the responsibility of the observer, or the support astronomer if present, to generate the archive tape (D-tape), and operations staff will normally provide a copy tape (C-tape) in FITS format on 9-track tape, Exabyte or DAT at the request of the observer. Alternatively the observer can create his or her own copy of the data in FITS format, or with the VMS BACKUP utility, on any of these media.

D-tapes can be created on any VAX in the cluster which has access to the required storage device, but the normal procedure is to do this on the main data reduction VAX LPVE. The observer should log onto this machine in the OBSERVER account (password will be known to local staff), mount the tape on the required drive, then use the utilities `FITSINIT` (only for a new tape!) and `WRITE_FITS`, which are described in more detail in Sections 4.9 and 7.1. A C-tape for the observer can be done at the same time, or this can be done by La Palma staff; for the latter, a Tape Copy request form should be filled out, indicating what kind of C-tape is required.

3.8 Engineering terminals

In addition to the DMS and the Autoguider terminals, which are located on the control desk, there are three other terminals which allow access to various subsystems. These are located on a table behind the data reduction vaxstation (LPVS3), and close to the door which leads to the dome area. One of the three terminals is a network monitor which should only be used by La Palma technical staff. Use of the other terminals is normally restricted to technical staff and support astronomers, and with the increasing reliability of the VAX control system, should occur only rarely.

3.8.1 The PFIP engineering terminal

The PFIP engineering terminal provides a continuously updated display of the status of PFIP mechanisms, and of the network messages last sent and received by the PFIP 4ms, and the ability to send network messages directly to the PFIP 4ms. To choose this option select **PRIME** on rotary switch "A" on the selection box between the engineering terminals. The status of one mechanism, including position, encoder readings and error codes, is displayed on the terminal and updated every few seconds. Which mechanism this is can be changed by pressing one of the keys listed in the reverse video menu at the botton of the screen. Typing N allows the user to send a network message to the 4ms. Typing T enters transparent mode, this mode should only ever be used by experienced technical staff. Next to the terminal are two small loudspeakers, these are connected to microphones in the PFIP and alongside the atmospheric dispersion compensator respectively. These allow the user to hear what is happening at the top end.

3.8.2 The Cass A & G box engineering terminal

Rotary switch "A" can be set to **A-G**, which allows control of the Cassegrain A&G box from the 4ms. This is a much less sophisticated interface than that of the PFIP, but still allows the user to send network messages and interrogate mechanisms. The mnemonics used for control of the mechanisms are listed in local technical documentation.

3.8.3 The Engineering MIMIC

Selecting **MIMIC** on rotary switch "A" allows the user to issue commands to the engineering MIMIC, a 4ms microprocessor which runs a schematic display of the state of the Cassegrain A&G box and ISIS. Commands are available to switch between the three display pages, to examine mechanisms in detail, and to issue network commands to move any mechanism in any subsystem (not just the ones on the display). These are detailed in a guide called "*The WHT engineering MIMIC*", which should be present in the control room.

3.8.4 The Detector engineering control terminal

The Detector engineering control terminal can be used to communicate with one of the CCD controllers, including the autoguider CCD controllers. A limited number of CCD commands, used for assessing the performance of the CCDs and for taking test exposures when the VAX 4000 system computer is not available, are available to users and are documented in Section 8.3 of this manual. Rotary switch 'B" on the selection box between the engineering terminals must be set to the correct CCD controller.

Part IV
SETUP AND OBSERVING PROCEDURES

4 Setup and Observing Procedures

4.1 Starting the computer systems

The primary interface between the user and the instruments is a command language called ICL which runs off a VAX 4000 (currently LPVF), and the primary source of information for the user is the Mimic display, which is a graphical process running on the VAX 4000, but displaying on a VAXstation 3100 which runs DECWINDOWS MOTIF, a variant of X-windows. In order to display the data in real time, and in order to control the DMS, it is necessary to run the SPARCstation (currently lpss3), located next to the control desk. The sparcstation also runs MOTIF, but a slightly different variant thereof. The other important interface for the user is the Detector Memory System (DMS), running Imageforth/68K, which provides a data display and a number of setup routines. This section describes how to check that all of the necessary systems are running and are communicating over the utility network, and to get the user interfaces running.

Because DMS local control is via a window on the SPARCstation, and not a terminal, the observer account on the SPARCstation should be started up first. On the SPARCstation (lpss3) logon as **observer**, the password will be known to local support staff. *Usernames and passwords must be in the correct case.* MOTIF will start automatically, but the application to control the DMS must be started from the Programs menu. From the Programs menu start the following applications:–

- **DMS interface** This starts up the graphical tool for transferring data from the DMS. There may be several versions of this, and it is important to start the one corresponding to the current VAX software release; this information can be found on the white board in the control room.

- **IRAF...** - This application will start the SAOIMAGE display server; and terminal window running IRAF.

- **DMS WINDOW...** - This application will start a terminal window for local control of the Detector Memory System, this is also a FORTH system, so should also respond "ok" if it is running.

Next, it is important to check that the VAX 4000 (LPVF) and the DMS are running. LPVF is at the far end of the control room from the control desk, and is clearly labelled. The operator console for LPVF is near the computer, and it will be fairly clear from the paper output of this whether the computer is running. The DMS is in a VME rack in the second of the four blue cabinets to the left of the control desk. Its user interface consists of a terminal, mouse, and display screen towards the left hand end of the control desk. If the DMS appears not to be running, or to be running in a non-standard configuration, or you are unsure of the configuration, toggle the switch labelled **RESET** on the module labelled **IRONICS VMEbus** of the DMS. The display screen will refresh, and the DMS control window on the SPARCstation will display a system message, then leave a standard Forth prompt ("ok" and a carriage return).

When the DMS is running it is possible to check which other subsystems are communicating over the Utility Network. At the DMS control window type:–

```
?NET
```

The DMS will then attempt to communicate with each of the subsystems in turn, and after each attempt will report either:–

NO RESPONSE FROM <DEVICE>

or:–

Acknowledgement received from <DEVICE>.

See Table 7 for a list of the devices.

Table 7: Microprocessors on the Utility Network

DMS	The detector memory system itself
FOS	The 4ms microprocessor controlling the Faint Object Spectrograph
AGCA	The 4ms microprocessor controlling the Cassegrain A&G Box
ISIS	The 4ms microprocessor controlling the ISIS Spectrograph
TAUR	The 4ms microprocessor controlling the Taurus Fabry–Perot
UES	The 4ms microprocessor controlling the Utrecht Echelle Spectrograph
CCD0	The spare CCD controller
CCD1	The controller for the Red Arm CCD
CCD2	The controller for the Blue Arm CCD
CCD3	The controller for the FOS CCD
CCD4	The controller for the UES CCD
IPCS	The 4ms microprocessor controlling the Image Photon Counting System
AUT1	The VME microprocessor controlling the CCD Autoguider
SYS	The VAX 4000 System Computer
ENGM	The Engineering Mimic, which is a 4ms microprocessor
LDSS	The 4ms microprocessor controlling the Low-Dispersion Survey Spectrograph
PFIP	The 4ms microprocessor controlling the Prime Focus Instrument Platform
CCD6	The controller for the Prime Focus CCD
BAK	The backup system computer
TIME	The Time Service 4ms

If the DMS does not receive an acknowledgement even from itself there is most likely a fault with the Network Interface Unit (NIU) connecting the DMS to the Utility network, or with the cables between the DMS and the NIU. If the DMS receives acknowledgements only from those devices which are connected to the same NIU as the DMS, then there is most likely a fault in the connection between that NIU and the Utility network Ethernet cable. In any case, ask a Duty Tech for help.

If the DMS terminal window is not available then `?NET` can equally well be issued from the Autoguider terminal.

If any of the 4ms or VME microprocessors fail to respond, then it is most likely that they are either not running, or are not correctly cabelled to the NIUs. If a group of devices on the same NIU fails to respond then there may be a fault with that NIU, or the cables between that NIU and the utility network. NIUs have a recessed reset button at the rear, which can be pressed with the sharp end of a pencil.

If the System Computer fails to respond, then it is possible to restart the Utility Network software running on the Microvax. At the Operator's console log in to the captive account **UNET**, the password should be available near the console. This will stop and restart the Utility Network software on the VAX 4000.

If these simple remedies do not work then technical assistance should be sought. **To run the observing and data taking system the minimum configuration is DMS, AGCA or PFIP, SYS, AUT1 and the relevant CCD.**

Once it has been established that the relevant devices are communicating over the network the user interface to the System computer can be started. The user interface is usually run on the VAXstation located on the control desk, though it can be run on a spare VAXstation elsewhere in the control room, or the alphanumeric interface can be run on a terminal with the MIMIC being displayed on a VAXstation.

If using a VAXstation for alphanumeric input the user should first log on to this VAXstation as **OBSERVER**. The password will be known to local staff. On the VAXstation type:–

```
LPVG
```

This is defined as `SET HOST/LOG LPVG` and a logon message from the

VAX 4000 system computer will appear. The user should also log on to this computer as **OBSERVER**. The password is the same. If using a terminal for alphanumeric input the user should log straight onto this machine. The system computer will display various information about new software and about the system. Two items require particular attention:–

- The system will try to allocate the device **XAA0:** which is used for data transfer from the DMS. If it cannot do this it will display a message to this effect, this is usually because there is a terminal somewhere with observer logged on. In this case this XAA0: must be deallocated at that terminal, or the process logged out or deleted. Then XAA0: must be allocated at the observer's terminal.
- The system will display the amount of free disk space on the system and data disks. If the data disk is full some data from previous night should be deleted, after first checking that it has been backed up.

At the VAXstation or terminal type:–

```
ICL
```

The ICL command language will start and the procedures and command definitions will be loaded. The user will be prompted for initials and a committee (PATT or CAT) reference number for the programme. No adverse consequences will result if the user does not know the latter.

The user is then prompted for the configuration required; normally this will be one of the following options:–

- Prime Focus Imaging
- A&G + CCD
- ISIS + A&G + CCDs
- ISIS + A&G + CCDs + IPCS
- ISIS + A&G + FOS + CCDs

The D-tasks will the be started and the various subsystems initialised. If the initialisation of one subsystem fails it is *possible* that other subsystems will not be initialised, if this appears to be the case the subsystems can be initialised explicitly with the commands `ISIS_BEGIN`; `DMS_BEGIN`; `CAGB_BEGIN`; `FOS_BEGIN`; `AUT_BEGIN`; `PFIP_BEGIN` and `CCDINIT <ccdname>`. At this time, automatic ADC adjustment should be enabled by typing `ADC_AUTO ENABLE`.

Starting up ICL will also start up the telescope control system on the Microvax II telescope control computer.

4.2 Filter Changes

4.2.1 Changing Filters in the PFIP main filter wheel

The PFIP filter wheel has seven positions, into each of these positions a lobe which can hold a 125mm diameter filter is mounted. Adaptors are available for smaller filters. *Currently changing filters in the PFIP filter wheel is a fairly difficult and time consuming procedure, and it is not recommended to be carried out during the night.* The telescope must be positioned at the Access Park (AP3) position with the access gates open. Only experienced technical staff, including Telescope Operators, should attempt to position the telescope there. The Prime Focus Rotator should be positioned at a mount position angle of 90°. It is only possible to access filters opposite the main beam position. If only one filter is to be changed, it is necessary to put a filter diametrically opposed to this into the beam, for instance if you want to change the filter in position 7, then put the filter wheel into position 3 or 4. If a number of filters are to be changed, it is easier to withdraw the detent pin, when the filter wheel can be rotated by hand. To do this, select a negative filter position, in the range -1 to -7, from the PFIP engineering terminal. The cover for the filter wheel is on the left hand side of the instrument platform at mount position angle 90°; this can be removed by unscrewing by hand the six large bolts. Four cables pass through this filter wheel cover, these need to be disconnected carefully at the LIMPIT controller. The connectors are keyed LIMO connectors, and can only be replaced in the correct sockets. The cover can now be removed, passing the cables and connectors through the hole provided. Once the cover has been removed the filter wheel cannot be driven either from ICL or the engineering controller, even if these cables are reconnected.

With the filter wheel cover removed, eight 4mm allen screws which clamp the filter wheel slide can be slackened off (not removed). After this has been done, a spring loaded pin which holds the filter slide in can be lifted by hand, and the filter wheel retracted. When it is withdrawn by about 15cm, it is possible to access the two outermost lobes.

Filters within the lobes can be changed by taking the cover off the lobe with a small flat screwdriver. When handling 125mm filters it is important to wear gloves to avoid fingermarks on the filters. Alternatively the whole lobe can be changed using a 4mm allen key.

When mounting filters it is important to keep the filter wheel in balance. The adaptors for the smaller filters are heavier than the 125mm filters, and if two of these are to be mounted it is advisible to mount them on opposite sides of the filter wheel. Similarly if two positions are to be left empty, these should be on opposite sides of the wheel.

The filter wheel should then be slid back into the assembly, ensuring that the spring loaded pin locates correctly, and the eight allen screws holding the wheel against the slides should then be tightened. The cover can then be replaced, passing the cables through the hole, and the six large bolts inserted. Finally the LIMPIT should be recabled.

After changing filters the wheel should be initialised, by typing `PFILT INIT` at the ICL interface, or issuing `MFW102` from the engineering controller. The ICL procedure `PCHANGE` must be run to update filter names focus offsets. Once this is done, typing `PSETFOCUS ENABLE` will enable automatic filter focus offsets during later observing. During observing, filters in the PFIP main filter wheel may be changed by typing `PFILTER <filtername>`, where <filtername> is one of the available filters.

4.2.2 Changing Filters in the Auxiliary Port filter wheel

To change filters in the auxiliary filter unit the CCD cryostat and the auxiliary focus filter unit must be removed from the telescope. The former operation must be carried out by technical staff, and it is very unlikely that this will be possible during the night. With the cryostat removed, the cables connecting the shutter to the CCD controller and the filter wheel to the A&G box 4ms must be removed from the front plate of the auxiliary filter unit. The filter unit then can be removed by unscrewing a number (up to 12) small allen screws around the front plate, and lifting the front plate, to which the filter wheel is attached, off. The filter wheel is a standard INT wheel, and the filters are changed in a similar manner, they are held in place by spring loaded cylindrical washers. The washers can be mounted either way up on their posts, to allow for filters of different thicknesses.

4.3 Checking out the CCD

The CCD setup is simply a matter of typing `SETUP_CCD` <`channelname`> at the ICL interface, and taking the default for each prompt. CCD focus and tilt are set up once for each chip at each focal station, and the cryostat is then put back in precisely the same place using the micrometers attached. Tilt can only be checked and corrected on the sky.

The CCD should be checked by taking a bias frame (`BIAS` <`channelname`> or `GLANCE` <`channelname`> `0`) and an exposure with the shutter opening (e.g. `GLANCE` <`channelname`> `1`). Transfer the `BIAS` frame over to the SPARCstation and check the image header (e.g. with IRAF IMHEAD) to make sure all of the necessary information is there. In the event of problems:

- If the CCD fibre optic interface card (at the top of the second blue cabinet from the left hand end of the control desk) displays a light labelled **G.O.A.T.** then there is probably a fault with an optical fibre cable. A duty tech should be called.

- If there is an error light on the DICI card; or a **FIFO FULL** light on the CCD fibre optic interface card; then the DICI should be reset and the exposure repeated.

- If the data are clearly scrambled; or show a series of diagonal stripes then the CCD controller thinks the data frame is a different size to the DMS. The DMS should be reset, and the `SETUP` and `WINDOW` commands should be repeated at the ICL interface **FOR EVERY CCD IN USE**.

- If the previous procedure does not work then the CCD controller should be rebooted (with the `REBOOT` command rather than switching it off and on) and the procedure repeated.

- If the CCD shutter fails to open this will send a message to the ICL interface. This could be due to a fault on a shutter cable; to low nitrogen pressure to the telescope; or to a mechanical failure of the shutter. However before calling for technical assistance it is worth typing `UNJAM` at the relevant CCD controller to see whether this cures the fault.

- Diagonal stripes may be seen on `BIAS` frames. These are quite common and are due to electronic pick-up noise. These are usually at a sufficiently low level (ie. less than 1 ADU) as not to be a problem for most imaging applications, especially long exposures where they will be lost in the sky noise. However, if they are seen at higher levels, alert your SA or a Duty Tech.

4.4 Instrument Calibration Data

Once the CCD has been set up to obtain images of the correct format, the observer can begin taking calibration exposures. Normally the following calibration exposures are required:

- A number of "Bias" frames, which are dark exposures with zero exposure time. These can be taken with the `BIAS` command. These are often not required because the bias is structureless, and its absolute level can be determined from the overscan and underscan regions associated with each exposure (see Table 5). It is still good practice, however, to take a few `BIAS` frames at the beginning and/or end of each night.

- A single long dark exposure, which can also be taken with the `DARK` command. The dark count is very small, and a dark frame is usually used to measure the cosmic ray rate.

- Flatfields in each passband to be used. Flatfields can be obtained off the inside of the dome with the mirror covers open using a filament lamp which is kept in the WHT building (never use the fluorescent lamps, which have strong lines in them which can cause fringing with thinned chips), or off the twilight sky between about 10 and 40 minutes after sunset. U band flatfields, and flatfields with interference filters can be obtained at the bright part of this period, and other broad bands (in the order B,V,I,R) in the latter part. It is a good idea to shift the telescope by 20 arcsec–30 arcsec between exposures so that stars may be removed later. As a rule of thumb, try to get 30,000–40,000 counts per pixel, so as to have a high S/N flatfield. "Dark Sky Flats" can be created by the "shift and add" technique. Here the telescope is shifted ('dithered') in a raster pattern between program exposures and the Dark Sky Flat is obtained by taking the median of the stack of frames (each image is rescaled so that the sky level in each is the same); see article by D. Carter in Gemini **39**. Dark Sky Flats are also very useful for removing any fringes (which are due to interference of night-sky lines, and commonly seen in R and I exposures).

- Shutter Corrections. The CCD shutter takes a finite amount of time to open and close, which results in a difference between the nominal (ie. as recorded in the FITS header) and real exposure times. Furthermore, this difference can vary with position on the chip, depending on the shutter design. The shutter correction (i.e. the length of time it takes to open *and* close the shutter) can be determined by taking several (dome) flatfield frames of equal illumination but with different exposure times; in practice it is best to take a series of short exposure frames and one longer exposure frame. We have found that the shutter correction depends on Zenith Distance, and only slightly on position within the CCD frame. Here are some preliminary results:

  20 ZD: S.C.= 0.005 – 0.02 sec

  45 ZD: S.C.= 0.055 – 0.065 sec

  90 ZD: S.C.= 0.08 – 0.09 sec

  However, these numbers are based on only a small number of frames, and users are encouraged to take their own data (the dome flats can be done in the afternoon and are usually taken anyway), especially if they need high-precision photometry. In any case, exposure times of less than 2 seconds should be avoided (for a shutter correction of 0.05 sec, a 2 second exposure is 0.05 mag fainter than would be calculated from the nominal exposure time!).

4.5 Focusing the Telescope

The best way to determine the correct telescope focus is to use the ICL `FOCUSIMAGE` procedure (see Section 6.4). `FOCUSIMAGE` generates a single CCD frame with a number of equal length exposures of a star(s), with the telescope position and focus stepped between exposures (the first step is double so that the stepping direction can be determined). The resulting image can then be examined (e.g. with IRAF `IMEXAMINE`) to find the best focus. Once the best focus <position> has been determined, set the telescope focus by typing:

`FOCUS <position>` at the ICL interface.

The telescope focus will be automatically compensated for temperature changes.

To enable automatic compensation of the telescope focus for different filter thicknesses, type :

`PSETFOC ENABLE` at the ICL interface.

Similarly, `PSETGDFOC ENABLE` allows automatic adjustment of the Autoguider focus to compensate for different Autoguider filter thicknesses.
The database with the names and focus offsets of the filters in the main filter wheel can be updated using the ICL `PCHANGE` procedure. This should be done before `PSETFOC` is enabled. See Section B.7.2 for how to calculate focus offsets. It is a good idea to do a `FOCUSIMAGE` with all of the filters that will be used to check the calculated focus offsets, and adjust them if necessary. See Section 6.1 for more details of the above procedures.

4.6 Focal Station Setup

To setup the TCS for the desired focal station, the following ICL commands are necessary:
`LOAD DISK$USER1:[RL.TAG]TAG_PROCS`
`TAGLOAD`
These two commands load and run Robert Laing's `TAGLOAD` procedure, which is needed for the `GSSEARCH` procedure for acquiring guide stars (see Section 4.7). Next,
`ACQCONFIG <station>`,
where <station> is either Prime or Cass. Finally, if at Prime Focus, you should type:
`ADC_AUTO ENABLE`,
and the ADC will then be automatically adjusted for varying elevation.

4.7 Acquiring guide stars

Guide Star acquisition is done almost automatically with ICL software that uses the on-line Guide Star Server to predict guide probe coordinates for a star from the HST Guide Star Catalogue; the guide probe is then moved to the predicted star location. It may be necessary to first load the required ICL procedure; check with your Support Astronomer or local staff. You should also make sure there is a filter (e.g. V) in the autoguider filter wheel; change autoguider filters by typing `PAUTOFILT <filter>` at the ICL interface.

To find a guide star, type:

`GSSEARCH` at the ICL interface.

`GSSEARCH` will then find the brightest star in the autoguider field, and move the guide probe to that location; you should see the guide probe x,y values change on the `MIMIC` display. If GSSEARCH fails, this may be due to the Guide Star Catalogue disk not being mounted, and an error message to this effect should appear. If this is the case, a Duty Technician will likely need to be called to remount the disk. If all goes well, and `GSSEARCH` returns without any errors, type:

`FIELD` at the ICL interface,

which will take an image of the autoguider field and display it on the autoguider monitor.

Hopefully the star will be in the guiding box, but it may be necessary to center the star in the box by moving the guide probe in x and/or y:

`PGDX <X position>` , to move probe to given <X position>
`PGDY <Y position>` , to move probe to given <Y position>
`PGDXY <X Y position>` , to move probe to given <X Y position>

Then type `FIELD` again to redisplay the autoguider field. After some experimentation, you will know which directions on the autoguider field correspond to increasing/decreasing X,Y. ??THESE DIRECTIONS HAVE TO BE DETERMINED!! THEY WILL NOT CHANGE ...??

Once the guide star is centered in the guiding box, start the autoguider guiding by typing:

`FON` at the ICL interface.

Finally, to close the guide loop and start sending autoguider errors to the TCS, type:

`AUTOGUIDE ON` at the ICL or TCS interface; there is a programmed function key on the TCS terminal to do this.

You are now ready to begin an exposure. If the autoguider is not guiding well, you can try increasing the autoguider exposure time by typing:

`GUIINT <time>` at the autoguider interface, or
`SETINT <time>` at the ICL interface

where the time is in milliseconds. Guiding integration times can be as short as 50 milliseconds, but it is better to integrate for longer times if possible (1–2 seconds is typical); a sensible maximum is 10 seconds. It may also be necessary to increase the size of the guiding box by typing:

`GUISIZE <n>` at the ICL interface,

where <n> is the size of the guiding box in pixels. Finally, it is possible that the autoguider is not in good focus. Ask the TO for the previous night's value of the autoguider focus; the focus may be changed by typing

`PGDFOC <value>` at the ICL interface

To stop guiding at the end of an exposure, type:

`AUTOGUIDE OFF` at the TCS or ICL terminal, and:
`FOFF` at the ICL interface, or `GUIDE OFF` at the Autoguider interface.

4.8 Taking Data Frames

Once the object coordinates have been typed into the system computer and added to the object list, an object may be acquired by typing `GOCAT <object-name>` on the TCS interface (this is usually done by the TO). Although the WHT should point to within 3 arcsec, you might want to take a quick exposure to check that the object is indeed within the field; this can be done by typing:

`GLANCE <channel> <time>` at the ICL interface,

where the exposure time is in seconds, and <channel> is either `PFIP` or `AUX`. A `GLANCE` exposure will not be saved to the system disk, but may be saved to the SPARCstation via the DMS interface (without headers).

Once the object has been acquired, longer exposures may be obtained by typing:

`RUN` <`channel`> <`time`>,

where again the time is in seconds. Multiple exposures can be done by typing:

`MULTRUN` <`channel`> `n` <`time`>,

where n is the number of exposures.

A run may be prematurely ended via the following commands:

`ABORT` <`channel`>– data will be lost

`FINISH` <`channel`>– exposure is ended "gracefully", and data saved to disk with the new, lower exposure time

Finally, an exposure may be paused, and then continued, by:

`PAUSE` <`channel`>
`CONTINUE` <`channel`>

In order that cosmic ray events may be identified and removed in subsequent processing, it is recommended that long exposures be split into several shorter exposures. Each shorter exposure should be long enough to be sky-noise limited, in which case the only penalty to be paid is that of the extra readout time. As well, to improve flat-fielding, the telescope should be shifted ("dithered") between each exposure. The dithered frames can be combined later to produce a dark sky flatfield which can be divided into each program frame (once they have been dome flatfielded). This dark sky flat can also be used to remove fringing which is often seen in long R and I exposures. Users who are very concerned about registering their frames should think carefully about the radial variation of the field distortion; for instance, at 5 arcmin from the optical axis at Prime Focus, the radial distortion is $\sim 0.2''$ (see Section 1.1).

4.9 Photometric standards

The number, frequency and type of photometric standards will depend upon the scientific programme. At a bare minimum, one should observe enough standards to encompass the range in colour and airmass expected for program objects. For standard broad bands (UBVRI) there is a set of positions of photometric standards in the range 11.5<V<16.0 published by A.U. Landolt (*Astronomical Journal* **104**, *340, 1992*), a copy of which is kept in a folder in the control room. The positions of these standards are kept in a catalogue on the Telescope Control Computer; e.g. to move to Landolt standard SA 110 229, the TO simply types: `GOCAT 110-229`. See *La Palma Technical Note No. 95: Landolt Faint Photometric Standards* for more information. Users should be aware that some of these standards have only been observed 2 or 3 times by Landolt, and may not be suitable if high-precision photometry is required. At Prime Focus the fainter standards should be used, and exposure times will range from around two minutes at U to a few seconds at R and I. To make this more quantitative, a star with U $\simeq$ 11.5 will saturate (ie. counts $\geq$ 60,000 ADU) in 30 seconds. Saturation times for B=15.5, V=13.5, and R=13.5 are 120, 30, and 5 seconds respectively, for $1''$ seeing. There are several fields which would contain several standards within the 7.2 arcminute square field at prime focus. At the auxiliary port longer exposures are possible, but individual stars must be observed.

A useful set of fainter standards are the cluster sequences of L. Davis (unpublished), with typically 15 < V < 20 and 0.5 < (B−V) < 1.5. These data were taken at the 0.9m Kitt Peak telescope, and the field size is approximately 7 x 4.6 arcmin in size (thus fitting within the 7.2 arcmin field of the TEK2 chip at prime focus). Data and finder charts for these sequences may be found in the above folder in the control room, and also in Appendix A in this manual. Observers are reminded that these are unpublished data, and are available for use at your own risk. Because of the limited color coverage and small number of repeat observations for some field/filter combinations, observers should not rely solely on these standards, but rather use them in conjunction with other standard star data (e.g. the Landolt standards described above). As well, observers should limit themselves to stars brighter than V $\sim$ 18.5, as the errors increase rapidly for fainter stars.

Standard colour terms for the Tektronix chip at prime focus are given in Table 8 below; this information can also be found in the information browsers at La Palma and Cambridge and in the LPINFO system on the

Table 8: Colour terms for the TEK2 chip at Prime Focus. The Colour terms are given in the sense of (Observed − Landolt). These data were obtained with the Harris BVRI filters and the RGO glass U filter.

Filter	Filter Type	Fitted Colour	Colour Term	R.M.S.
U		(U−B)	−0.128	0.05
B		(B−V)	−0.064	0.03
V		(B−V)	−0.007	0.03
R		(V−R)	−0.029	0.03
I		(R−I)	−0.123	0.02

Cambridge VAX GXVG. See also Appendix B.

4.10 Writing data tapes

The first tape copy of the data (the D-tape) is kept by the observatory and stored in the data archive. Currently D-tapes are in FITS format on DAT. It is the responsibility of the observer to write the D-tape. To do this log in to the observing computer LPVE (VAX) as OBSERVER (password known to local staff). Type `STARTFITS` to initialize FITS procedures. The tape must be mounted foreign (e.g. `MOUNT/FOR MUA1:`). *New* FITS tapes have to be initialised with `FITSINIT`, and then they may be written on with `WRITE_FITS`, in each case follow the prompts. `WRITE_FITS` will append to tapes (i.e. existing files will not be overwritten *unless* `FITSINIT` is issued first), and about 400 full frame Tek 1024 images can be stored on a single DAT.

The Observer's copy of the data (the C-tape) can be a copy of the D-tape, which can be requested by filling in a tape copy request form, a Backup of the data directories, or a separate DAT or Exabyte written in exactly the same way as the D-tape. The FITS writing routines can be run from any username, and two tapes may be written simultaneously (see Sections 4.9 and 7.1 for more details).

4.11 Data reduction

The ING Sun cluster runs the IRAF data reduction package and all of the Starlink software collection, including Figaro and Kappa. Data files are stored in .SDF format on the VAX system computer; these files can be transferred to the Suns with ftp, and used directly in Figaro and Kappa. To get files into IRAF format, they can be transferred individually using the DMS to SPARC interface, or else transferred from the VAX via a FITS DAT or Exabyte, or disk FITS files, which can be transferred by ftp. There are IRAF manuals and cook-books in blue binders in the control room.

Part V

QUICK REFERENCE GUIDE

5 Quick Reference Guide

This section is intended to provide a guide for the experienced user, and contains one line summaries of some of the most commonly used commands, arranged approximately in the order of an observing session. More detail of the individual commands is given in Part VI. In this section some abbreviations (set up as Defstrings under ICL) are used. If in doubt about a particular function please refer to Part VI.

5.1 Starting Up

– Create a DECTERM window on the observing VAXStation (usually, LPVS2) and login as OBSERVER (password known to local staff).

– Now type `LPVG` and login to LPVG (the VAX 4000) with the same username and password

– Read the news and then see the diskspace available on the datadisk displayed

– Type `ICL` to start the observing system. Answer the prompts – the MIMIC displays are usually put on LPVS2.

– As the MIMIC screens fill with mechanism positions and settings, check for any 'bad status' colours. The colour coding is as follows:

Green:	set ok	Blue:	mechanism moving
Red:	error status	White:	not in use

– During 3pm handover tests, SA or observer should check for bad status, and move some mechanisms in ISIS, A&G Box, Autoguider and AuxPort (if being used). Also, `SETUP` and `WINDOW` all the CCDs to be used.

5.2 Focal Station Setup

– check the MIMIC to see that the necessary filters are in the appropriate filter wheel. Type `PCHANGE` if necessary to change filter names and/or focus offsets. Type `PAUTOFILT <filter>` to change the autoguider filter if necessary.

– it is recommended to set the telescope focus to the previous night's value (see TO's logbook); this is done by typing `FOCUS <value>`, where the focus value is in mm (a `FOCUSIMAGE` should be done at the start of observing to fine-tune the focus).

– type `PSETFOCUS ENABLE` to enable automatic adjustment of telescope focus for different filter thicknesses

– type `PSETGDFOC ENABLE` to enable automatic adjustment of autoguider focus for different autoguider filter thicknesses

– type `ADC_AUTO ENABLE` to enable automatic adjustment of the ADC when the telescope changes elevation

– type `LOAD DISK$USER1:[RL.TAG]TAG_PROCS`, followed by `TAGLOAD` to run the `TAGLOAD` procedure needed for automatically acquiring Guide Stars.

– type `ACQCONFIG <channel>` to do the focal station setup, where <channel> is `PFIP or AUX`.

5.3 Taking Data - the Data Acquisition System

A typical command specifies a *channel* (`PFIP` or `AUX`); an exposure time *t* (sec); a *title*; an observation type *obstype* (e.g., `FLAT`, `BIAS`, `TARGET`, etc); and sometimes the number *num* of the output file in a scratch area. The DAS commands are:

`RUN`	*chann*	*t*	*title*	Take an exposure of an astronomical target
`TARGET`	*chann*	*t*	*title*	Same as `RUN`
`FLAT`	*chann*	*t*	*title*	Take a flat-field exposure
`SKY`	*chann*	*t*	*title*	Take a sky-flat exposure
`DARK`	*chann*	*t*	*title*	Take a dark exposure (shutter not opened)
`BIAS`	*chann*		*title*	Take a 0-sec exposure
`FLASH`	*chann*		*title*	Ditto with preflash
`GLANCE`	*chann*	*obstype*	*t*	A 'quicklook' - put data in DMS only (no headers)
`KEEP`	*chann*		*title*	Keep a `GLANCE` file
`SCRATCH`	*chann*	*num*	*obstype*	*t title*. As `RUN`, but data saved as file *num* in scratch area
`WINK`	*chann*	*num*	*obstype*	*t title*. As `SCRATCH`, but no headers are collected
`PROMOTE`	*num*			Promote scratch file *num* to normal `RUN` file status

It is possible to take a set of n identical exposures with the command

`MULTRUN` *chann* n *title*

and there are similar commands `MULTFLAT`, `MULTARC`, etc.

DAS commands to modify or end exposures are:

`PAUSE`	*chann*		Pause an exposure
`CONTINUE`	*chann*		Continue a paused exposure
`FINISH`	*chann*		End an exposure and save the data
`ABORT`	*chann*		End an exposure and discard the data
`NEWTIME`	*chann*	t	Set a new exposure time

There is a special ICL procedure,
`FOCUSIMAGE`,
to find the best telescope focus; see Sections 4.5 and 6.4 for more details.
There is an ICL procedure,
`GSSEARCH`,
to automatically find a guide star from the HST Guide Star Catalog, and move the guide probe to the appropriate place (see Sections 4.6 and 6.3 for more details).

The command

`DIR`

lists the `RUN` and `SCRATCH` files taken during the night.

5.4 Setting Up The CCDs

The typical configuration is CCD3=AUX, CCD6=PFIP.
This may change; `DET_SHOW_CONF` shows the actual configuration.

Check when CCDs were last filled with liquid N_2 and fill if necessary. Check CCD temperatures are correct (see MIMIC screen for CCD1, etc).

`SETUP PFIP(AUX)`	to setup the default formats: 1280 in X, 1180 in Y for EEV3 & EEV6; 1124×1124 for Tek
`WINDOW PFIP(AUX)`	to window, just answer the questions.
`DISABLE_WINDOWS PFIP(AUX)`	to disable windows (and `ENABLE_WINDOWS` to restore).

`SEND CCDn OBEY CANCEL_WINDOWS MOVE` h	to clear windows completely (h=head number)
`<speed> PFIP(AUX)`	to change CCD readout speed: `SLOW, STANDARD, QUICK, TURBO, NONASTRO`. `TURBO`, `NONASTRO` not recommended for science exposures.
`BIN PFIP(AUX)`	set on-chip binning factors in X and Y

5.5 The DMS Display

- CCD images are read out into the DMS and displayed on the screen.
- The first CCD exposure read out after startup (or a DMS reset) will just be displayed as a small ikon. Click the cursor on this ikon (with the LH mouse button) for a full size display. You can switch between CCDs.
- The mouse is disabled during CCD readout (when a BUSY message is displayed).

5.6 Autoguiders

5.6.1 Prime Autoguider

To start or stop, type START-UP and SHUT-DOWN on the autoguider keyboard. Check N_2 flow on start up. There will be a ball meter, at prime focus it is on the turntable diagonally opposite the autoguider head; at Cassegrain it is above the red arm CCD cryostat.

ICL Interface

`PGDX` n	Sets guide probe X position (n=0–110000 microns).
`PGDY` n	Sets guide probe Y position (n=0–20000 microns).
`PGDXY` m n	Sets guide probe X and Y position (m=0–110000 microns, n=0–20000 microns).
`PGDFOC` n	Sets guide probe focus (n=0–14100 microns).
`SETINT` n	Sets integration time (n=50–50000 msec; typical 1–2s)
`GSSEARCH`	to find guide star and move guide probe
`FIELD`	takes exposures and finds guide star
`FON`	initiates 'following' by autoguider

`AUTOGUIDER ON`	tell T/S to initiate closed-loop autoguiding
`AUTOGUIDER OFF`	tell T/S to stop autoguiding
`GUISIZE` n	Sets size of guiding box (default 30 pixels)
`FOFF`	terminates the autoguider 'following'

Other commands available on the **autoguider keyboard** :

`PRIME`	selects the prime focus autoguider
`SETINT` n	sets integration time for the field in millisecs
`FIELD` n	does a full frame readout and searches for up to n stars.
`GUIDE ON`	to start guiding, averaging over i integrations
`GUIDE OFF`	to stop guiding
`GUISIZE` n	to change the size of the guiding box
`>> and <<`	to rotate colour look-up table
`+TAU and −TAU`	to change horizontal scale of guide error display
`+SCALE and −SCALE`	similarly vertical scale

5.6.2 Cassegrain Autoguider

`AUTORADIAL` n	n=0–40000 microns
`AUTOTHETA` n	n=0–180000 millidegrees
	N.B. for values below 35000, the probe may vignette the slit
`AUTOFOCUS` n	n=0–6000 microns (typically 1500-2500)
`AUTOFILT`	selects EMPTY, CLEAR, OPAQUE, B, V or I
`GSSEARCH`	to automatically find guide star and move guide probe

5.7 Data Files

- To see what files have been saved on the 4000 look in the directory: DISK$WHTDATA2:[OBSDATA.dd-mm-yyyy].

  From ICL use: `DCL DIR DCT_OBSDIR:[dd-mon-year]`.

- To write a FITS tape from the 4000 :-

  - Login to LPVE as OBSERVER in an independent session, password known to local staff.
  - `ALLOCATE MUDO:, MUEO` Allocate one of the tape drives that are connected to LPVE
  - `MOUNT/FOR/DENS=6250 MUDO: or MUEO:` Mount the tape
  - `FITSINIT` and answer the questions
  - `WRITE_FITS` ditto.

  To write an EXABYTE in FITS format:

  - Login to LPVE as OBSERVER
  - `MOUNT/FOREIGN MUE1:`
  - `STARTFITS` ... to initialize FITS procedures
  - `FITSINIT` ... for a *new* tape only, answer the questions
  - `WRITE_FITS` ... ditto.

  To write DAT in FITS format:

  - Login to LPVE as OBSERVER
  - `MOUNT/FOREIGN MUE3: or MUB3:`
  - `STARTFITS`
  - `FITSINIT` ... for a *new* tape only, answer the questions
  - `WRITE_FITS` ... ditto.

5.8 Shutdown

- `SHUT-DOWN` the Autoguider (type this on the autoguider keyboard).
- `EXIT` and then logoff from LPVF and the VAXstation.
- Fill CCDs with liquid N_2.
- Enter requests for next day in the Telescope Log book, and enter faults in the FAULT database on LPVS3 (login to LPVS3 as user FAULT, no password required, and fill out fault form; CTRL-Z to exit).
- Make sure C and D archive tapes are started

Part VI
COMMAND LISTS

6 Commands entered at the ICL interface

This section describes commands which can be entered at the ICL interface to control one or more subsystems.

Notation:

- Examples of commands entered at the terminal are in typewriter font: `AUXFILTER R`;
- Angle brackets denote parameter values or character strings: `<angle>`;
- Square brackets denote optional input: `[x,y]`; all other parameters are obligatory;

6.1 Prime Focus Instrument Platform Commands

6.1.1 ADC

Sets both the inner and outer elements of the atmospheric dispersion corrector to a given position angle; the inner element is set to the value given, and the outer element to minus the value given. This command can also be used to stop or initialise the mechanisms.

Format:	`ADC <angle>`
Examples:	`ADC 45.5`
	`ADC INIT`
	`ADC STOP`
Units:	Degrees, or the string `STOP` or `INIT`.
Range:	-90.0 to +90.0
Comments:	This command is not available while automatic ADC adjustment is in operation.

6.1.2 ADC_AUTO

Switches on or off automatic updating of the ADC position by the PFIP control task.

Format:	`ADC_AUTO <parameter>`
Parameter:	This can be `ENABLE` or `DISABLE`.

Example: `ADC_AUTO ENABLE`
Comments: While automatic adjustment is in operation, the telescope elevation is checked every 30 seconds by the PFIP D-task, and if necessary the ADC elements are moved to the appropriate positions.

6.1.3 ADI

Sets the inner element of the atmospheric dispersion corrector to a given position angle. This command can also be used to stop or initialise the mechanism.
Format: `ADI <angle>`
Examples: `ADI 45.5`
`ADI INIT`
`ADI STOP`
Units: Degrees, or the string `STOP` or `INIT`.
Range: -90.0 to +90.0
Comments: This command is not available while automatic ADC adjustment is in operation.

6.1.4 ADO

Sets the outer element of the atmospheric dispersion corrector to a given position angle. This command can also be used to stop or initialise the mechanism.
Format: `ADO <angle>`
Examples: `ADO 45.5`
`ADO INIT`
`ADO STOP`
Units: Degrees, or the string `STOP` or `INIT`.
Range: -90.0 to +90.0
Comments: This command is not available while automatic ADC adjustment is in operation.

6.1.5 FOCUS

Sets the telescope focus.
Format: `FOCUS <value> (in mm)`
Example: `FOCUS 86.0`
Units: mm

Range: ??
Comments: A good starting point is the previous night's focus.

6.1.6 PAUTOFILT

Moves the Autoguider filter wheel in the PFIP to the given filter name or position. This command can also be used to stop or initialise the mechanism.

Format: `PAUTOFILT <filter>`
Examples: `PAUTOFILT 3`
`PAUTOFILT GG375`
`PAUTOFILT INIT`
Comments: The names of the filters mounted in the filter wheel are kept in a database which can be modified with the command `PCHANGE`. Filters can be specified either by the name in the database, or by a position in the range 1 to 6. The filter wheel can also be stopped by giving `STOP` as the parameter to the command, and initialised by specifying `INIT` as the parameter.

6.1.7 PCHANGE

Interactive procedure to update the database containing the names and focus offsets of the contents of the main filter wheel, and the names of the contents of the autoguider filter wheel.

Format: `PCHANGE`
Comments: Similar to the procedure `WHEEL` on the INT and JKT, this procedure prompts for the names, and in the case of the main filter wheel the focus offsets, for the filter in each position in turn.

6.1.8 PF_MODE

This sets the PFIP 4ms operational mode, the options are FULL or ADC_ONLY.

Format: `PF_MODE <mode>`
Example: `PF_MODE FULL`
Comments: The only allowed modes are `FULL` and `ADC_ONLY`, and in normal operation for imaging the mode should always be `FULL`. If the mode is changed the PFIP 4ms will be reset, which will take about 45 seconds, during which time no further PFIP commands should be issued.

6.1.9 PFILT

Moves the Main filter wheel in the PFIP to the given filter name or position. This command can also be used to stop or initialise the mechanism.

Format: `PFILT <filter>`

Examples: `PFILT 3`
`PFILT V`
`PFILT INIT`

Synonym: `PFILTER`

Comments: The names of the filters mounted in the filter wheel are kept in a database which can be modified with the command `PCHANGE`. Filters can be specified either by the name in the database, or by a position in the range 1 to 7. The filter wheel can also be stopped by giving `STOP` as the parameter to the command, and initialised by specifying `INIT` as the parameter. The main filter wheel currently takes about 40 seconds to move from one position to another.

6.1.10 PFILTSTATUS

Lists the contents of the main filter wheel and the focus offsets.

Format: `PFILTSTATUS`

Synonym: `PFILTST`

6.1.11 PFIP_CANCEL

Cancels an outstanding PFIP action.

Format: `PFIP_CANCEL <action>`

Examples: `PFIP_CANCEL GDXPOS`
`PFIP_CANCEL ALL`

Comments: A list of the actions which are allowed as parameters to this command can be obtained by typing `PFIP_CANCEL`. However the most likely use of this command is after a 4ms reset, when the safest procedure is to type `PFIP_CANCEL ALL`.

6.1.12 PFIP_UPDATE

Requests status data for a mechanism from the 4ms.

Format: `PFIP_UPDATE <mechanism>`

Examples: PFIP_UPDATE GDXPOS
PFIP_UPDATE ALL
Comments: A list of the mechanisms which are allowed as parameters to this command can be obtained by typing PFIP_UPDATE.

6.1.13 PFSTATUS

Gives a text summary of the status of the PFIP.
Format: PFSTATUS
Synonym: PFST
Comments: This command summarises in a text format the status of all of the PFIP mechanisms. It is useful mainly when the MIMIC process is not running.

6.1.14 PGDFOC

Sets the prime focus autoguider focus position. This command can also be used to stop or initialise the mechanism.
Format: PGDFOC <value>
Examples: PGDFOC 7400
PGDFOC INIT
Units: Microns.
Range: 0 to 14100
Comments: Instead of a value, the strings STOP and INIT can be given to this command to stop or initialise the mechanism. If autoguider focus compensation is enabled (with PSETGDFOC) then the reference value used for other filters will be adjusted by the same amount as the current focus is being adjusted by.

6.1.15 PGDX

Sets the X position of the prime focus autoguider probe. This command can also be used to stop or initialise the mechanism.
Format: PGDX <value>
Examples: PGDX 56700
PGDX INIT
Units: Microns.
Range: 0 to 110000.
Comments: Instead of a value, the strings STOP and INIT can be given to this command to stop or initialise the mechanism.

6.1.16 PGDXY

Sets the X and Y positions of the prime focus autoguider probe. This command can also be used to stop or initialise the mechanisms.

Format: `PGDXY <xvalue> <yvalue>`
Examples: `PGDXY 10300 3050`
`PGDXY INIT`
Units: Microns.
Range: 0 to 110000.
Comments: Instead of a value, the strings `STOP` and `INIT` can be given to this command to stop or initialise the mechanisms. Due to hardware restrictions this command can only move or initialise the X and Y mechanisms *sequentially*. The two parameters can be a number and a string, for instance `PGDXY 3000 INIT` will move the x motion to 3000, and initialise the y mechanism, but if the first parameter is `INIT` then both mechanisms will be initialised. `PGDXY` must be given two parameters.

6.1.17 PGDY

Sets the Y position of the prime focus autoguider probe. This command can also be used to stop or initialise the mechanism.

Format: `PGDY <value>`
Examples: `PGDY 10700`
`PGDY INIT`
Units: Microns.
Range: 0 to 20000.
Comments: Instead of a value, the strings `STOP` and `INIT` can be given to this command to stop or initialise the mechanism.

6.1.18 PSETFOC

Enables or disables automatic compensation of the telescope focus for different filter thicknesses.

Format: `PSETFOC <value>`
Examples: `PSETFOC 98.24`
`PSETFOC DISABLE`
Synonym: `PSETFOCUS`
Units: Millimetres of travel of the top end of the telescope.

Comments: The argument of this command can be `ENABLE`, `DISABLE` or a focus value. If a focus value is given compensation is enabled, with the specified value as the reference position for the current filter. If `ENABLE` is given then compensation is enabled with the current focus value as the reference position for the current filter. If automatic compensation is enabled then automatic adjustment of the Autoguider focus with `PSETGDFOC` should also be enabled.

6.1.19 PSETGDFOC

Enables or disables automatic adjustment of the Autoguider focus to allow for automatic compensation of the telescope focus for different filter thicknesses.

Format: `PSETGDFOC <value>`
Examples: `PSETGDFOC 8300`
`PSETGDFOC DISABLE`
Synonym: `PSETGDFOCUS`
Units: Microns.
Range: 0 to 14100
Comments: The argument of this command can be `ENABLE`, `DISABLE` or a focus value. If a focus value is given compensation is enabled, with the specified value as the reference position for the current main filter. If `ENABLE` is given then compensation is enabled with the current focus value as the reference position for the current main filter. This command does **not** compensate for different thicknesses of Autoguider filters; the Autoguider filter wheel is after the output end of the coherent fibre bundle, and such adjustment is not possible.

6.2 Cassegrain A&G Box Commands

Only a subset of the Cass A&G box commands relevant to imaging are listed here.

6.2.1 AGINIT

Initialises one of the mechanisms in the Cassegrain A&G box.
Format: `AGINIT <mechanism>`

Examples: `AGINIT COMPFILTA`
`AGINIT ALL`

Comments: Mechanisms which can be initialised include: COMPFILTA; COMPFILTB; AUTOFILT; AUTOFOCUS; AUTOTHETA; AUTORADIAL; AUXFILT; TVFOCUS; TVFILT; TVSCALE; ACQCOMP; SLITVIEW; LARGEFEED and SMALLFEED. To initialise all of the A&G box mechanisms type `AGINIT ALL`.

6.2.2 AGMIRROR

Moves a specified A&G box mirror into the beam, or all mirrors out of the beam.

Format: `AGMIRROR` <`mirrorname`>

Example: `AGMIRROR SLITVIEW`

Synonyms: `AGCOMP` (≡ `AGMIRROR ACQCOMP`)
`AGSLIT` (≡ `AGMIRROR SLITVIEW`)

Comments: Valid parameters are: ACQCOMP; SLITVIEW; LARGEFEED; SMALLFEED and OUT.

6.2.3 AGUPDATE

Updates the status of a mechanism as displayed on the MIMIC display.

Format: `AGUPDATE` <`mechanism`>

Examples: `AGUPDATE COMPLAMPS`
`AGUPDATE ALL`

6.2.4 AUTOFILT

Sets the position of the Autoguider filter wheel.

Format: `AUTOFILT`

Example: `AUTOFILT CLEAR`

Comments: Possible values are: B; V; I; CLEAR; EMPTY and OPAQUE. Note that AUTOFOCUS will need to be adjusted when moving from B, V, or I to EMPTY, but not when moving from B, V, or I to CLEAR.

6.2.5 AUTOFOCUS

Sets the Autoguider focus.

Format: `AUTOFOCUS <focusvalue>`
Example: `AUTOFOCUS 3500`
Units: Microns.
Range: 0 to 6000.
Comments: The autoguider focus must be adjusted after the telescope focus has been set to focus on a guide star.

6.2.6 AUTORADIAL

Sets the radial position of the guide probe.
Format: `AUTORADIAL <radialposition>`
Example: `AUTORADIAL 10000`
Units: Microns.
Range: 0 to 40000.

6.2.7 AUTOTHETA

Sets the angular position of the guide probe.
Format: `AUTOTHETA <thetaposition>`
Example: `AUTOTHETA 50000`
Units: Millidegrees.
Range: 0 to 180000.
Comments: Note that values less that 35000 may cause the probe to vignette the slit viewing optics.

6.2.8 AUXFILTER

Moves the auxiliary port filter wheel to a given position.
Format: `AUXFILTER <filterposition>`
Example: `AUXFILTER 3`
Range: 0 to 5.
Comments: The filter wheel has positions 0 to 5, and the names of the filters mounted in each position are usually listed on the white board in the control room.

6.2.9 TV_DIRECT_12

Selects the direct viewing position at a scale of 12 arcsec/mm.
Format: `TV_DIRECT_12`

Comments: Procedure which moves the mirrors to the ACQCOMP position, selects a scale of 12 arcsec/mm and the correct value of TVFOCUS.

6.2.10 TV_DIRECT_5

Selects the slit viewing position at a scale of 5 arcsec/mm.

Format: `TV_DIRECT_5`

Comments: Procedure which moves the mirrors to the ACQCOMP position, selects a scale of 5 arcsec/mm and the correct value of TVFOCUS.

6.2.11 TVFILT

Moves the filter wheel in front of the TV camera to a named filter.

Format: `TVFILT <filtername>`

Example: `TVFILT R`

Comments: Possible values are: B; V; R; CLEAR and EMPTY. The TV focus must be adjusted when changing from EMPTY to one of the other positions. **Note that there may be an opaque mask in position EMPTY; if so position CLEAR should be used instead.**

6.2.12 TVFOCUS

Sets the TV focus.

Format: `TVFOCUS <focusvalue>`

Example: `TVFOCUS 15000`

Units: Microns.

Range: 0 to 17500.

Comments: To adjust the TV focus so that the TV is focussed on the slit, or so that a star is in focus on the TV in direct mode.

6.2.13 TVSCALE

Sets the TV scale.

Format: `TVSCALE <tvscalevalue>`

Example: `TVSCALE 5`

Comments: Puts the correct focal reduction optics (or no optics at all) in front of the TV camera for a specified scale (in arcsec/mm), either in slit viewing or direct mode. Allowed values of the TV scale are 5 and 12.

6.3 Autoguider Commands

6.3.1 AUTOGUIDER

Tells T/S to start or stop closed-loop autoguiding.

Format: `AUTOGUIDER <ON/OFF>`

Examples: `AUTOGUIDER ON`

Comments: Valid values are ON or OFF. This must be done to start or stop closed-loop autoguiding, and is preceded by `FON`.

6.3.2 FIELD

Causes the CCD autoguider to read out its whole field of view and look for a suitable guide star.

Format: `FIELD`

Comments: Does not return control to the user until this process is complete. Equivalent to `FIELD 1` at the autoguider interface.

6.3.3 FOLLOW

Causes the CCD Autoguider to follow a star image and to send error signals to the Telescope Control Computer, or to stop doing so.

Format: `FOLLOW <onoroff> <n>`

Examples: `FOLLOW ON 1`

Synonyms: `FON` (≡ `FOLLOW ON 1`)
`FOFF` (≡ `FOLLOW OFF 1`)

Comments: Valid values of the first parameter are ON and OFF; the second is the number of Autoguider integrations per guiding error is normally 1. Equivalent to `GUIDE ON` and `GUIDE OFF` at the Autoguider terminal. `FOLLOW` does not start the telescope autoguiding; it is necessary to issue the `AUTOGUIDER` commands to the TCS, either through the ICL interface or at the TCS terminal to do this.

6.3.4 GSSEARCH

Automatically finds a guide star from the HST Guide Star Catalog, and moves the guide probe to the correct location.

Format: `GSSEARCH`

Comments: `GSSEARCH` finds the *brightest* guide star; sometimes this will saturate the autoguider CCD unless very short integration times are used. `GSSEARCH` automatically informs the T/S of the guide probe position, so this does not need to be done by hand.

6.3.5 GUISIZE

Sets size of guiding box.

Format: `GUISIZE <n>`

Examples: `GUISIZE 40`

Comments: <n> is the size of the guiding box in pixels.

6.3.6 SETINT

Changes the Autoguider integration time.

Format: `SETINT <integrationtime>`

Example: `SETINT 4000`

Units: Milliseconds.

Comments: Equivalent to `SETINT <integrationtime>` at the Autoguider terminal. Note that there is now only one Autoguider integration time, which is used for both acquiring and guiding.

6.4 Data Taking Commands - CCD Detectors

CCD data are taken and stored with the Data Acquisition System, which provides a large range of commands for taking data of various types, and storing the data with or without the header information in various forms on the VAX discs. A description of the system, together with a complete list of the commands, is given in "William Herschel Telescope Instrument control and data acquisition system user manual", by S.W. Unger & G.T. Rixon, and only a subset of the commands, relevant to observing with CCDs at Prime Focus, are listed here. Many commands do almost identical things, for instance the commands `RUN`, `FLAT`, and `SKY` differ only in one header item in the data file. The commands `SCRATCH` and `PROMOTE` are intended for use by automatic setup procedures yet to be written.

6.4.1 ABORT

Terminate an exposure early, abandoning the data.

Format:	`ABORT <channel>`
Channel:	The name of the CCD data acquisition channel to be used.
Examples :	`ABORT RED`
Comments:	This command terminates the current CCD exposure, throwing away the data.

6.4.2 BIAS

Takes a single bias frame (a zero second exposure), and transfers the data plus headers to an HDS file on the system computer.

Format:	`BIAS <channel> ["<string>"]`
Channel:	The name of the CCD data acquisition channel to be used.
Title:	A title for the observation (optional)
Examples :	`BIAS RED "Bias frame 5"`
Comments:	As for the RUN command, except that exposure time will be zero, and the observation type is set in the headers as being a BIAS exposure.

6.4.3 BIN

Bins a CCD detector

Format:	`BIN <channel> <xbin> <ybin>`
Channel:	The name of the CCD data acquisition channel to be binned.
Xbin:	The binning factor in X. This must be an integer in the range 1 – 10.
Ybin:	The binning factor in Y. This must be an integer in the range 1 – 10.
Examples :	`BIN PFIP 2 2`
Comments:	This command sets the binning factors on the named channel in both X and Y, and enables windowing and binning on the CCD.

6.4.4 CCDINIT

Initialises a CCD.

Format:	`CCDINIT <detectorname>`
Example:	`CCDINIT PFIP`

Comments: Initialises a CCD and updates the MIMIC display with data from the CCD controller. This is performed in the startup sequence, and this command is only required if the startup sequence fails.

6.4.5 CONTINUE

Continue a paused CCD exposure.

Format: `CONTINUE <channel>`

Channel: The name of the CCD data acquisition channel to be used.

Examples : `CONTINUE PFIP`

Comments: This command resumes a paused CCD exposure, opening the CCD shutter. The shutter will not be opened if it was closed when the exposure was paused (as in the case of a dark exposure). The command will be aborted if no exposure is in progress.

6.4.6 DARK

Takes an exposure without opening the CCD shutter, and transfers the data plus headers to an HDS file on the system computer.

Format: `DARK <channel> <time> ["<string>"]`

Channel: The name of the CCD data acquisition channel to be used.

Time: The exposure time in seconds

Title: A title for the observation (optional)

Examples : `DARK PFIP 9999 "Measuring dark counts"`

Comments: As for the RUN command, except that the CCD shutter is not opened, and the observation type is set in the headers as being a DARK exposure.

6.4.7 DIR

Lists the run and scratch files taken during the night.

Format: `DIR`

Comments: Lists the files in the directories to which run and scratch files are currently being written. Normal DCL qualifiers (e.g. `/SIZE`) are accepted. One can also examine the log file displayed on the VAX 3100 to see the `RUNS` that have been done that night.

6.4.8 DISABLE_WINDOWS

Disables windows and binning factors previously set up on a CCD detector

Format:	`DISABLE_WINDOWS <channel>`
Channel:	The name of the CCD data acquisition channel.
Examples :	`DISABLE_WINDOWS AUX`
Comments:	This command disables windowing and binning of the CCD. The command does not delete the systems memory of window parameters and binning factors, it only stops the system applying it. The windows and binning can be reenabled with the command ENABLE_WINDOWS.

6.4.9 DISKSPACE

Reports the available diskspace on the data disk and on the home disk of the OBSERVER.

Format:	`DISKSPACE`

6.4.10 ENABLE_WINDOWS

Enables windows and binning factors previously disabled on a CCD detector

Format:	`ENABLE_WINDOWS <channel>`
Channel:	The name of the CCD data acquisition channel .
Examples :	`ENABLE_WINDOWS AUX`
Comments:	Where windowing and binning of the CCD have been disabled using the DISABLE_WINDOWS command, this command reenables them.

6.4.11 FINISH

Terminate an exposure early, saving data and headers to disk.

Format:	`FINISH <channel>`
Channel:	The name of the CCD data acquisition channel to be used.
Examples :	`FINISH PFIP`
Comments:	This command terminates the current CCD exposure, saving the data to disk as if the exposure had completed normally.

6.4.12 FLAT

This is equivalent to the RUN command, but intended for exposures of flat fields rather than astronomical targets

Format: `FLAT <channel> <time> ["<string>"]`
Channel: The name of the CCD data acquisition channel to be used.
Time: The exposure time in seconds
Title: A title for the observation (optional)
Examples : `FLAT AUX 1.5 "Flatfield"`
Comments: As for the RUN command, except that the observation type is set in the headers as being a flatfield exposure.

6.4.13 FOCUSIMAGE

Procedure to generate a single CCD frame containing a number of equal length exposures on the sky. Between each exposure the telescope position and telescope focus are stepped. The resulting image is the equivalent of a "focus plate" and from the image sizes the correct telescope focus can be determined.

Format: `FOCUSIMAGE`
Prompts: FOCUSIMAGE prompts for:-

- Channel name (`PFIP` or `AUX`);
- Start Focus Position (mm, ask TO for previous night's value);
- Focus Step (mm, recommended values 0.1 to 0.2);
- Number of steps (typically 5 to 10);
- Telescope step (arcsec, typically 10–20);
- Exposure time (seconds, typically 5–10)

Comments: FOCUSIMAGE is an ICL procedure which co-ordinates telescope focus and position changes with the CCD shutter, then reads out the resulting image into the DMS, and into a scratch file on the VAX. The procedure puts in a double length position step between the first and second focus positions, to aid identification of the images. The position offsets are in the X direction as understood by the TCS, and both position and focus offsets can be positive or negative. At the end of the procedure the telescope is moved to the original position, and the focus is returned to the start focus position. The focusimage can be transferred to the SPARCstation, and IRAF `IMEXAMINE` used to determine the best focus (ie. smallest FWHM).

6.4.14 GLANCE

Takes an exposure and transfers the data into the Detector Memory System for inspection, but not to the system computer.

Format: GLANCE <channel> <obstype> <time>

Channel: The name of the CCD data acquisition channel to be used.

Time: The exposure time in seconds

Obstype: The observation type. Valid observation types are SKY, BIAS, DARK, FLAT, and TARGET.

Examples : GLANCE PFIP FLAT 5

Comments: This command is intended for a quick–look at the data, to verify for example that the intensity level is as expected before carrying out a proper exposure. The data will be lost when the next exposure is carried out on the same data acquisition channel. To save the data, use the KEEP command.

6.4.15 KEEP

Copies a previously completed glance exposure to disk on the system computer, collecting headers and assigning a run number in the process.

Format: KEEP <channel> ["<title>"]

Channel: The name of the CCD data acquisition channel to be used.

Title: A title for the observation (optional)

Examples : KEEP PFIP

Comments: The system will report the allocated run number.

6.4.16 KILLMULT

Stops a sequence of multiple exposures.

Format: KILLMULT <channel>

Channel: The name of the CCD data acquisition channel.

Example: KILLMULT AUX

Comments: The current exposure in the series is left to complete normally, and all pending exposures are cancelled. The channel becomes ready for another command when the current exposure completes. KILLMULT can be followed by FINISH or ABORT for a complete stop.

6.4.17 MULTRUN

Takes a sequence of exposures, all of the same exposure time

Format: `MULTRUN <channel> <nruns> <time> ["<title>"]`
Channel: The name of the CCD data acquisition channel to be used.
Time: The exposure time in seconds
Example: `MULTRUN AUX 25 60 "AX DRACO 25 exposures"`
Comments: There also commands `MULTFLAT`, `MULTBIAS`, `MULTDARK` which have similar formats, except that `MULTBIAS` does not require a time.

6.4.18 NEWTIME

Change the exposure time of an exposure in progress.

Format: `NEWTIME <channel> <time>`
Example: `NEWTIME PFIP 1200`
Channel: The name of the CCD data acquisition channel to be used.
Time: The exposure time in seconds
Comments: The system will not accept an exposure time less than the current exposed time.

6.4.19 NONASTRO

Sets the CCD readout speed to NONASTRO SPEED.

Format: `NONASTRO <channel>`
Channel: The name of the CCD data acquisition channel.
Example: `NONASTRO AUX`
Synonym: `READOUT_SPEED NONASTRO`
Comments: This sets the CCD to its fastest readout mode, which should not be used for normal observing.

6.4.20 PAUSE

Pauses a CCD exposure.

Format: `PAUSE <channel>`
Channel: The name of the CCD data acquisition channel to be used.
Examples : `PAUSE AUX`
Comments: This command suspends the current CCD exposure, closing the CCD shutter. The command will be aborted if no exposure is in progress.

6.4.21 PROMOTE

Promotes a scratch datafile to the main data area on the system computer, assigning it a run number in the process.

Format: `PROMOTE <filenum>`
Filenum: The number of the scratch file
Examples : `PROMOTE 5`
Comments: The system will report the allocated run number. However, since the headers for the observation are collected when the data is originally taken, the run number will not appear in the headers.

6.4.22 QUICK

Sets the CCD readout speed to QUICK SPEED.

Format: `QUICK <channel>`
Channel: The name of the CCD data acquisition channel.
Example: `QUICK AUX`
Synonym: `READOUT_SPEED QUICK`
Comments: This sets the CCD to a readout mode slightly faster than STANDARD (with slightly higher read noise), and is recommended for broadband imaging.

6.4.23 RAT_WAIT

RAT_WAITs for an exposure to complete before returning control to ICL.

Format: `RAT_WAIT <channel> <timeout>`
Channel: The name of the CCD data acquisition channel to be used.
Timeout: The maximum time to wait (seconds)
Examples : `RAT_WAIT AUX 90`
Comments: The commands for carrying out CCD exposures normally return control to ICL before they complete. Whilst this is desirable in normal operation, it makes it impossible to write ICL procedures to carry out a number of exposures sequentially (as in a focus run for example). Such ICL procedures can be produced using the WAIT command (see section ? for examples). The timeout parameter of the WAIT command forces it to return an error to ICL if the exposure does not complete; it is recommended that timeouts be made generous.

6.4.24 RUN

Takes an exposure of an astronomical target, and transfers the data plus headers to an HDS file on the system computer.

Format: `RUN <channel> <time> ["<string>"]`
Channel: The name of the CCD data acquisition channel to be used.
Time: The exposure time in seconds
Title: A title for the observation (optional)
Examples : `RUN PFIP 1.5 "NGC1068"`
Synonym: `TARGET`
Comments: This command takes a single exposure of an astronomical target, collects header information pertaining to that exposure, and transfers both data and headers into an HDS file on the system computer. During the observation the system will report the run number allocated, and will announce the start and end of the exposure. The user will be informed once the data has been written to disk; until this notification has been received, no further exposure can be carried out on this detector channel. Exposures cannot be carried out until the detector has been set up using the SETUP command.

6.4.25 SCRATCH

Takes an exposure, and transfers the data plus headers to a numbered HDS file in the scratch area on the system computer.

Format: `SCRATCH <channel> <filenum> <obstype> <time> ["<string>"]`
Channel: The name of the CCD data acquisition channel to be used.
Filenum: The number of the scratch file
Obstype: The observation type. Valid observation types are SKY, BIAS, DARK, FLAT, and TARGET.
Time: The exposure time in seconds
Title: A title for the observation (optional)
Examples : `SCRATCH PFIP 5 SKY 60`
Comments: As for the RUN command, except that the data is finally transferred not to the main data area on the system computer but to a scratch area. This command is intended primarily for use with setup procedures.

6.4.26 SETUP

Sets up the default detector format, and prepares a channel for taking data.

Format: `SETUP <channel>`

Channel: The name of the CCD data acquisition channel to be used.

Examples : `SETUP PFIP`

Comments: The system will read the default detector format from the configuration database and set the detector up accordingly. The user will be informed when the set-up is complete. No exposures can be made until the channel has been set up by this command.

6.4.27 SKY

This is equivalent to the RUN command, but intended for sky exposures rather than observations of astronomical targets.

Format: `SKY <channel> <time> ["<string>"]`

Channel: The name of the CCD data acquisition channel to be used.

Time: The exposure time in seconds

Title: A title for the observation (optional)

Examples : `SKY AUX 1.5 TITLE="Twilight"`

Comments: As for the RUN command, except that the observation type is set in the headers as being a sky flat field.

6.4.28 SLOW

Sets the CCD readout speed to SLOW SPEED.

Format: `SLOW <channel>`

Channel: The name of the CCD data acquisition channel.

Example: `SLOW AUX`

Synonym: `READOUT_SPEED SLOW`

Comments: This sets the CCD to its slowest readout mode, which is probably too slow for imaging applications.

6.4.29 STANDARD

Sets the CCD readout speed to STANDARD SPEED.

Format: `STANDARD <channel>`

Channel: The name of the CCD data acquisition channel.

Example: `STANDARD AUX`

Synonym: `READOUT_SPEED STANDARD`
Comments: This sets the CCD to its STANDARD readout mode, suitable for narrow band imaging.

6.4.30 TURBO

Sets the CCD readout speed to TURBO SPEED.
Format: `TURBO <channel>`
Channel: The name of the CCD data acquisition channel.
Example: `TURBO AUX`
Synonym: `READOUT_SPEED TURBO`
Comments: This sets the CCD to its TURBO readout mode, usually only used for setting up or for short test exposures. The penalty of the fast readout is a higher read-noise and the onset of non-linearity at lower ADU levels.

6.4.31 WINDOW

Windows a CCD detector
Format: `WINDOW <channel>`
Channel: The name of the CCD data acquisition channel to be windowed.
Examples : `WINDOW PFIP`
Comments: The system will prompt the user for the number of windows to be set-up, and the origin and size of each window. Windowing and binning of the CCD will be enabled. **At present use of more than one window on a CCD is not recommended**.

6.4.32 WINK

Takes a scratch exposure as for the SCRATCH command, except that no headers are collected.
Format: `WINK <channel> <filenum> <obstype> <time> [TITLE="string"]`
Channel: The name of the CCD data acquisition channel to be used.
Filenum: The number of the scratch file
Obstype: The observation type. Valid observation types are: SKY, BIAS, DARK, FLAT, and TARGET.
Time: The exposure time in seconds
Title: A title for the observation (optional)

Examples: WINK PFIP 5 FLAT 60
Comments: As for the SCRATCH command, except that no headers are collected.

6.5 Assorted Telescope and Setup Commands

6.5.1 TAGLOAD

Loads the TAGLOAD procedure, necessary for later use with GSSEARCH to automatically acquire guide stars.
Format: LOAD DISK$USER1:[RL.TAG]TAG_PROCS
Format: TAGLOAD
Comments: Note that these are two *separate* commands.

6.5.2 ACQCONFIG

Sets up the TCS for the desired focal station.
Format: ACQCONFIG <station>
Station: The name of the focal station to be used (PRIME or CASS).
Examples: ACQCONFIG PRIME

6.6 Other DMS Commands

6.6.1 DMS_ABORT_TRANS

Aborts a data transfer from the DMS to the system computer.
Format: DMS_ABORT_TRANS SYS

6.6.2 DMS_CLOSE_BUFF

Closes all DMS buffers.
Format: DMS_CLOSE_BUFF

6.6.3 DMS_RESET

Software reset of the DMS.
Format: DMS_RESET

6.6.4 DMS_START

Reads the status of the DMS into the system computer.
Format: DMS_START

6.7 MIMIC Commands

6.7.1 MIMIC PAGES

Lists the names of the available MIMIC pages.

Format: `MIMIC PAGES`

Comments: Pages can then be selected using `SCREEN`.

6.7.2 MIMIC UPDATE

Refreshes the screen if it appears to have become out of date.

Format: `MIMIC UPDATE`

6.7.3 MIMIC_START

Starts up the MIMIC.

Format: `MIMIC_START`

Comments: An interactive procedure to start up the MIMIC. Will prompt for the node name of the VAXstation to run it on.

6.7.4 MIMIC_STOP

Closed down the MIMIC.

Format: `MIMIC_STOP`

6.7.5 SCREEN

Selects a MIMIC screen.

Format: `SCREEN <screenname>`

Example: `SCREEN PFIP`

Comments: Selects a screen from the list given by `MIMIC PAGES`. This is usually only used if there is a fault with the mouse on the VAXstation.

7 DCL Level Commands for the VAX 4000

These commands can be issued on the VAX 4000 when logged in as OBSERVER, and with default directory U1:[OBSERVER]. They can either be issued in a separate session, from the $ prompt, or from the ICL interface by typing:-

```
DCL <COMMAND> [<parameters>]
```

7.1 Tape Writing Commands

Tapes can be written in two formats, FITS format or as a VMS backup of the data files. Two tapes are normally written: the D-tape or archive tape, which must be in FITS format; and the C-tape or copy tape, which can either be a direct copy of the D-tape, or a tape written by the observer in the format of his choice. The VMS Backup utility is described in detail in the DEC manual set, this section will describe the commands required to produce FITS tapes.

7.1.1 FITSINIT

To initialise a new FITS tape.

Format: `FITSINIT`

Comments: The program requires the tape to be mounted on a tape drive on the one of the VAXes, normally tape drive MUB3 or MUE3. It prompts for the name of the tape user and owner. It should only be used for new tapes.

7.1.2 WRITE_FITS

To write data files to a fits tape.

Format: `WRITE_FITS`

Comments: The program requires the tape to be mounted on a tape drive on one of the VAXes, normally tape drive MUC1:. If it is a new tape then `FITSINIT` must be run first. The program prompts for the numbers of the first and last files to be written to tape. The program will search for files with these numbers on the WHT data disc (DISK$WHTDATA:), and write them as FITS files to the specified tape. There is no problem if a file in the sequence is missing. If WRITE_FITS is run to a tape which already has Fits files on it, the program will search for the end of the tape before starting to write, i.e. it will not overwrite existing files *unless* a FITSINIT is issued.

8 Local Subsystem Commands

8.1 Autoguider Commands

8.1.1 ?NET

Checks what devices are accessible across the network from the autoguider.

Format: `?NET`

Comments: Sends a message to each device in turn across the network and waits for an acknowledgement. Logs which devices acknowledge and which do not. Useful for diagnosing network problems.

8.1.2 ?REGS

Displays the contents of several Autoguider registers.

Format: `?REGS`

Comments: Displays the contents of several Autoguider registers, including fibre header number and pixels expected.

8.1.3 ACQWIND

Specifies the acquisition window for the Autoguider.

Format: `ACQWIND` <x1> <y1> <x2> <y2>

Example: `ACQWIND 50 50 300 200`

Defaults: At Prime focus: x1=179, y1=65, x2=297, y2=185
At Cassegrain focus x1=27, y1=15, x2=379, x2=272.

Comments: Sets the acquisition field on the Autoguider CCD in pixels. The user is not allowed to specify a window which extends *outside* this default window in any direction.

8.1.4 CASS

Selects the Cassegrain Autoguider.

Format: `CASS`

Comments: There are also commands to select other autoguiders, including `UES`, `PRIME`, and `AUTOFIB`.

8.1.5 CCDCUR

Allows the positions of stars to be measured on an autoguider exposure

Format: `CCDCUR`

8.1.6 CONFIG

Menu driven command for informing the autoguider control computer of the excact configuration of autoguider heads and CCD controllers and serial port allocations in use.
Format: `CONFIG`

8.1.7 DARK-PATTERNS

Takes and averages a series of 20 dark frames to subtract from the CCD images, and updates the dark frame for the current camera. This command should be issued whenever the operating temperature is changed.
Format: `DARK-PATTERNS`

8.1.8 EXPOSURE

Takes a full frame CCD exposure, and displays the unprocessed image.
Format: `EXPOSURE <exposuretime>`
Example: `EXPOSURE 3000`
Units: `Milliseconds.`

8.1.9 FIELD

Scans the field searching for guide stars.
Format: `FIELD <nstar>`
Example: `FIELD 1`
Default: nstar defaults to 1 if no argument is given.
Comments: Causes the CCD autoguider to read out and search for guide stars, marking the brightest star in the field to use as a guide star.

8.1.10 GUIDE

Starts the Autoguider tracking a star or stops it.
Format: `GUIDE ON <n> or GUIDE OFF`
Example: `GUIDE ON 1`
Comments: Starts or stops the Autoguider following a guide star. n specifies the rank of the guide star in order of brightness, and defaults to 1.

8.1.11 GUILOOPS

Changes the number of integrations over which the autoguider averages before sending an error signal to the VAX.

Format: `GUILOOPS <nloop>`
Example: `GUILOOPS 5`
Default: nloops=1

8.1.12 GUISIZE

Changes the size of the guiding box.

Format: `GUISIZE <npixels>`
Example: `GUISIZE 30`
Default: npixels=15
Range: 5 to 100
Comments: This can be used to increase the size of the guiding box in bad seeing conditions.

8.1.13 GUIWIND

Sets the position of the centre of guiding box in CCD pixels

Format: `GUIWIND <x> <y>`
Example: `GUIWIND 235 120`
Defaults: X and Y default to the position of the currently selected star.
Comments: This can be used to reacquire the guide star when the telescope is moved by an accurately known amount, or to start guiding at a predetermined position. At prime focus the the entire guiding box must be within the fibre window.

8.1.14 HELP

Menu driven online help

Format: `HELP`
Comments: Displays a menu of commands for which help screens can be displayed.

8.1.15 PRIME

Selects the Prime Focus Autoguider

Format: `PRIME`

Comments: There are also commands to select other autoguiders, including `UES`, `CASS`, and `AUTOFIB`.

8.1.16 SCAN

Displays DICI errors.
Format: `SCAN`
Comments: Displays summary of unexpected data, including fibre header code, and error count.

8.1.17 SELECT STAR

Selects one of the stars logged by `FIELD` for guiding.
Format: `SELECT STAR <nstar>`
Example: `SELECT STAR 3`

8.1.18 SETINT

Changes the integration time.
Format: `SETINT <integrationtime>`
Example: `SETINT 4000`
Units: Milliseconds.

8.1.19 SHUT–DOWN

Shuts down the Autoguider and warms the chip up.
Format: `SHUT-DOWN`
Comments: Starts a shut down sequence for the Autoguider by warming the CCD chip up above 0°C. This process takes about 5 minutes and the observer should check that it works. An alternative command to warm the chip up is `STEMP 20`.

8.1.20 STARLOG

Displays the log of stars found by the last `FIELD` command.
Format: `STARLOG`

8.1.21 START–UP

Starts up the Autoguider.

Format:	`START-UP`
Comments:	Starts up the Autoguider by turning on the nitrogen flushing and cooling the chip to around -30°C. If in any doubt the observer should verify by checking the flowmeter attached to the outlet that the nitrogen flow has indeed been turned on.

8.1.22 STATS

Causes a statistics summary for the current guiding run to be displayed on the autoguider display screen. This display includes mean and standard deviation of the seeing and transparency values, which are useful for assessment of the weather conditions.

Format:	`STATS`
Comments:	This command is unreliable if used whilst the autoguider guide loop is active.

8.1.23 STEMP

Sets the target temperature for the current autoguider chip.

Format:	`STEMP <temperature>`
Example:	`STEMP -35`
Units:	Degrees C.

8.1.24 TEMP

Causes the temperature on the autoguider display to be updated.

Format:	`TEMP`

8.1.25 TV

Starts or stops continuous readout of the selected window

Format:	`TV <status>`
Example:	`TV ON`
Comments:	TV ON turns on continuous readout, TV OFF turns it off. TV without an argument will toggle to the opposite state from current.

8.2 DMS commands

The DMS has many functions, in addition to those provided by the user interface (the mouse). Those described here are useful for setting up the detectors; for diagnostic information when something goes wrong; or for taking and temporary storage of data if the VAX 4000, or the parallel link between the VAX 4000 and the DMS, is not available.

8.2.1 ?IMAGES

Lists the image files available on the DMS disc.

Format: `?IMAGES`

Commets: Lists the named images on the DMS disc available for temporary storage of data. Images of three formats exist, full format for large and small CCDs and 2560 by 200 for IPCS data. Only images of these formats can be stored in these files.

8.2.2 ?NET

Checks what devices are accessible across the network from the DMS

Format: `?NET`

Example: `?NET`

Comments: Sends a message to each device in turn across the network and waits for an acknowledgement. Logs which devices acknowledge and which do not. Useful for diagnosing network problems.

8.2.3 ?REGS

Displays the contents of several DMS registers.

Format: `?REGS`

Comments: Displays the contents of several DMS registers. Of particular interest are registers 2,5,8,B and E, which contain the number of pixels the DMS is expecting from the CCDs assosciated with buffers 1 to 5. Useful for diagnostic purposes if it is suspected that a CCD readout might have hung, or some pixels might have been lost

8.2.4 DEV?

Lists the image buffers which are open.

Format: `DEV?`

Comments: Used to check whether the image buffers have the correct format.

8.2.5 RECOVER

Initialises the DMS display.

Format: `RECOVER`

Synonym: `START-DISPLAY`

Comments: This can be used if the display hangs up or if the lookup table or cursor position appear to be corrupted. It can sometimes, but not usually, recover from the Opal board crash, when the display screen goes blue. It does not affect the data.

8.2.6 RECOVER–DATA

To ensure that data stored in the DMS is ok after a hardware reset.

Format: `RECOVER-DATA`

Comments: After a hardware reset of the DMS this procedure will ask the user if valid data is present in each DMS image buffer, and if it is will display that data on the DMS screen.

8.2.7 ZM

Allows the zoomed area on the image display to be moved.

Format: `ZM`

Comments: Allows the user to move the zoomed area around in the image. The rectangle can be moved with the mouse, pressing $\boxed{\text{SELECT1}}$ on the mouse changes the zoomed area to the current area of the rectangle. Pressing the return key exits from ZM.

8.3 CCD controller commands

8.3.1 ?OPEN .

Interrogates a CCD shutter to see whether it is open.

Format: `?OPEN .`

Comments: If the response is -1 then the shutter is open; if it is 0 then the shutter is closed. Other responses indicate a problem with the shutter.

8.3.2 1P

Commands after this refer to Physical Head 1.

Format: `1P`

Comments: After issuing this command further CCD commands will affect Physical Head 1, until this is changed by issuing `2P`. Commands that require the correct Physical Head to be set include: `OPEN`; `CLOSE`; `UNJAM`; `RED`; `PIC` and `CLR`. Consult RGO technical staff to find out which Physical head number refers to the CCD you are using.

8.3.3 2P

Commands after this refer to Physical Head 2

Format: `2P`

Comments: After issuing this command further CCD commands will affect Physical Head 2, until this is changed by issuing `1P`. Commands that require the correct Physical Head to be set include: `OPEN`; `CLOSE`; `UNJAM`; `RED`; `PIC` and `CLR`.

8.3.4 1V

Commands after this refer to Virtual Head 1.

Format: `1V`

Comments: After issuing this command further CCD commands will affect Virtual Head 1, until this is changed by issuing `2V`. Commands that require the correct Virtual Head to be set include: `QUICK SPEED`; `STANDARD SPEED`; `CONFIG`; `RED`; `PIC`; `CLR` and local binning and windowing commands. Consult RGO technical staff to find out which Virtual head number refers to the CCD you are using.

8.3.5 2V

Commands after this refer to Virtual Head 2

Format: `2V`

Comments: After issuing this command further CCD commands will affect Virtual Head 2, until this is changed by issuing `1V`. Commands that require the correct Virtual Head to be set include: `QUICK SPEED`; `STANDARD SPEED`; `CONFIG`; `RED`; `PIC`; `CLR` and local binning and windowing commands. Consult RGO technical staff to find out which Virtual head number refers to the CCD you are using.

8.3.6 CLOSE

Closes a CCD shutter.
Format: `CLOSE`

8.3.7 CLR

Clears a CCD.
Format: `CLR`
Comments: **This command currently only works from the Network vocabulary, invoked by typing** `NETWORK`.

8.3.8 NETWORK

Invokes the Network vocabulary.
Format: `NETWORK`

8.3.9 NONASTRO SPEED

Sets the readout speed to NONASTRO.
Format: `NONASTRO SPEED`
Comments: This is the fastest (and highest noise) of the CCD readout speeds, and is not normally used for serious observations. If you wish to run the CCD in this mode you must issue this command after every hard or soft reset of the CCD controller. This command is only available from the VHT vocabulary, if it appears not to work type `VHT` then try again. This instruction can also be issued over the network from the DMS terminal, to do this type >`CCDn`, where n denotes the network address of the CCD in question; then type `NONASTRO`.

8.3.10 OPEN

Opens a CCD shutter.
Format: `OPEN`

8.3.11 PIC

Takes an exposure and reads it out.
Format: `<headnumber> 0 PIC`
Comments: Local command to clear the chip, take an exposure of an exposure time previously set up with the `SEX` command, and read the chip out. A buffer must have been set up in the DMS to receive the data. The first parameter is the head number and is 1 or 2. The second parameter can be used to delay the start time. **This command currently only works from the Network vocabulary, invoked by typing** `NETWORK`.

8.3.12 QUICK SPEED

Sets the readout speed to QUICK.
Format: `QUICK SPEED`
Comments: This provides a quicker readout of the CCD, and hence less dead time between exposures, together with a slightly higher dynamic range, at the expense of somewhat higher readout noise. If you wish to run the CCD in this mode you must issue this command after every hard or soft reset of the CCD controller. This command is only available from the VHT vocabulary, if it appears not to work type `VHT` then try again. This instruction can also be issued over the network from the DMS terminal, to do this type >`CCDn`, where n denotes the network address of the CCD in question; then type `SPEEDY`.

8.3.13 REBOOT

Software reset of the CCD controller.
Format: `REBOOT`

8.3.14 RED

Reads out a CCD.

Format: `RED`

Comments: Reads out a CCD into an existing DMS buffer. Useful in diagnosing CCD problems. **This command currently only works from the Network vocabulary, invoked by typing** `NETWORK`.

8.3.15 SET-TIME

Sets the internal clock of the CCD controller.

Format: `<HH:MM:SS> SET-TIME`

Example: `14:28:00 SET-TIME`

Comments: This affects the time stamp which will appear in the headers of CCD exposures. If accurate times are required this should be reset every night. **Currently the seconds must be zero**.

8.3.16 SET-DATE

Sets the date for the internal clock of the CCD controller.

Format: `<dd:mm:yy> SET-DATE`

Example: `01:10:93 SET-DATE`

Comments: This affects the date recorded in the headers of CCD exposures.

8.3.17 SEX

Sets exposure time.

Format: `<headnumber> <exposuretime> SEX`

Example: `1 10000 SEX`

Units: Milliseconds.

Comments: Local command to set exposure time. The first parameter is the CCD head number, and is 1 or 2. **This command currently only works from the Network vocabulary, invoked by typing** `NETWORK`.

8.3.18 SLOW SPEED

Sets the readout speed to SLOW.

Format: `SLOW SPEED`

Comments: This is the slowest (and lowest noise) of the CCD readout speeds, and is not normally used for direct imaging. If you wish to run the CCD in this mode you must issue this command after every hard or soft reset of the CCD controller. This command is only available from the VHT vocabulary, if it appears not to work type `VHT` then try again. This instruction can also be issued over the network from the DMS terminal, to do this type >`CCDn`, where n denotes the network address of the CCD in question; then type `SLOW`.

8.3.19 STANDARD SPEED

Changes the readout rate to STANDARD.

Format: `STANDARD SPEED`

Comments: This resets the readout speed of the CCD to the default speed. This command is only available from the VHT vocabulary, if it appears not to work type `VHT` then try again. This instruction can also be issued over the network from the DMS terminal, to do this type >`CCDn`, where n denotes the network address of the CCD in question; then type `SLOUCH`.

8.3.20 T–STAT

Displays the temperature of the CCD chip in the current physical head.

Format: `T-STAT`

8.3.21 T–SHOW

Displays temperature information for both Physical heads.

Format: `T--SHOW`

8.3.22 TELE

Displays telemetry from a CCD controller.

Format: `<headnumber> TELE`

Example: `2 TELE`

Comments: Displays voltages and currents from the CCD controller, with their nominal values. This is useful for diagnosing faults with CCDs and controllers.

8.3.23 TURBO SPEED

Sets the readout speed to TURBO.

Format: `TURBO SPEED`

Comments: This is the second fastest of the CCD readout speeds. If you wish to run the CCD in this mode you must issue this command after every hard or soft reset of the CCD controller. This command is only available from the VHT vocabulary, if it appears not to work type `VHT` then try again. This instruction can also be issued over the network from the DMS terminal, to do this type >`CCDn`, where n denotes the network address of the CCD in question; then type `TURBO`.

8.3.24 UNJAM

Unjams a CCD shutter which is stuck.

Format: `UNJAM`

Comments: This is the first thing to try if a CCD shutter appears to stick. Issuing the `UNJAM` command may free the shutter, this can be checked with the `OPEN` and `CLOSE commands`

8.3.25 VHT CONFIG

Displays the virtual head table configuration of a CCD controller.

Format: `VHT CONFIG`

Comments: This is actually two commands: VHT selects the Virtual Head Table and CONFIG displays the configuration. This command is useful because along with the windowing and binning information it also displays the readout speed (Quick or Standard) selected. This information is not available on the VAX Mimic. The correct Virtual head must be selected (with 0V or 1V) before this command is issued.

9 The DMS User Interface

The Detector Memory System has a mouse driven user interface which provides the user with some data assessment facilities. The mouse has three buttons and is moved around on a reflecting pad. The mouse drives a cursor on the screen which is in the form of a cross. The cursor can be moved anywhere on the screen. The screen consists of an image display area and a menu area; the menu area appears in the top right hand corner of the screen. When CCD data is displayed there are also one or more "icons", small CCD images, these enable the user to switch between CCD buffers displayed in the main display area.

9.1 Use of the Mouse

Moving the mouse on the reflective pad moves the cursor anywhere on the screen including the menu area, the icons, and the image area. The mouse has three buttons, which are designated SELECT1 (the left hand key); SELECT2 (the centre key); and ESCAPE (the right hand key). SELECT1 is used to select a function or to perform an operation; SELECT2 is only used in those instances where two functions can be performed from a single menu option (such as increasing or decreasing the contrast); and ESCAPE is used to return to the menu from an option, or to return to the main menu from another menu.

9.2 The Menu Structure

9.2.1 The Main Menu

The Main Menu enables the user to select any of the other available menus, and the ZOOM function. Any item can be selected by placing the cursor on the menu name, and pressing SELECT1. The options are:-

- **PREFERENCES** - this menu has not been implemented and trying to select it will have no effect.
- **DISPLAY** - Selecting this menu gives various options for changing the contrast and lookup table of the image displayed in the image display area.
- **ZOOM** - This does not select a menu, but is an option. After selecting the ZOOM option with SELECT1, pressing SELECT1 again zooms in, while SELECT2 zooms out. Moving the mouse on the keypad while the display is zoomed moves the cursor in the image in the same sense as the mouse is being moved on the pad, while attempting to keep the cursor in the centre of the screen. This results in the image moving on the screen in the opposite sense to that in which the mouse

is being moved, with some timelag. $\boxed{\text{ESCAPE}}$ returns the display to normal (i.e. not zoomed), and returns the user to the Main menu.

- **STATISTICS** - Selecting this menu gives various options for defining windows in the data area, and for statistical operations on the data within these windows.
- **WINDOWS** - This menu gives options for defining windows on the DMS screen, but is not currently used.
- **3D MODES** - This menu gives options for examining three dimensional data arrays. These are not useful for any of the ISIS data acquisition modes implemented to date.
- **SCREENS** - This menu allows the user to select between types of data (i.e. CCD or IPCS), and will in future be used to select between display formats.

9.2.2 The Display Menu

The display menu allows the user to choose between lookup tables and to change the contrast of the display. There are two lookup tables, a colour table and a greyscale. When driven from the Mouse interface, the chosen table always covers a range between 0 and 2^n, where n is in the range 1 to 16. However the display wraps around, so the full range of allowed data values (0 to 65535) is covered by $2^{(16-n)}$ wraps of the lookup table.

The following options can be selected by placing the cursor on the option name on the display menu and pressing $\boxed{\text{SELECT1}}$:–

- **GREY** - Selects the Greyscale lookup table and leaves the user in the Display menu.
- **COLOUR** - Selects the Colour lookup table and leaves the user in the Display menu.
- **REVERSE** - Reverses the lookup table and leaves the user in the Display menu.
- **SHIFT** - After selecting this option with $\boxed{\text{SELECT1}}$, pressing $\boxed{\text{SELECT1}}$ again increases the contrast of the display, i.e. reduces the range that one wrap of the lookup table covers, by a factor of two. $\boxed{\text{SELECT2}}$ decreases the contrast of the display, i.e. increases the range that one

wrap of the lookup table covers, by a factor two. $\boxed{\text{ESCAPE}}$ returns the user to the Display menu, leaving the lookup table as it was last set.

- **NORMAL** -

9.2.3 The Statistics Menu

The Statistics menu allows the user to define windows and perform statistical operations on data within these windows. These include cross sections in X and Y, made by collapsing a window onto the X or Y axis. These functions perform differently depending upon whether they are operating on IPCS data or CCD data, for IPCS data they sum the data in the perpendicular direction, whereas for CCD data they average them. This difference must be borne in mind when, for instance, estimating count rates per pixel for IPCS data, and estimating atmospheric transparency from a CCD spectrum of a spectrophotometric standard. At present only two windows are available for all data screens and all buffers, these remain in place until adjusted with the SET WINDOW options, even when the user switches between IPCS and CCD data. A future enhancement will provide separately defined windows for each data buffer.

With the X-CUT and Y-CUT functions it is possible to perform a preliminary sky subtraction. To do this Window 1 is placed on the object spectrum, and Window 2 on a suitable sky area. It is not necessary to make Window 2 exactly the same width as Window 1, as appropriate scaling is applied. It is not necessary to place Window 2 precisely in the spectral direction, as the limits in this direction of the sky region are changed to those of Window 1.

Options available from the Statistics menu are:-

- **SET WINDOW1** - After selecting this option with $\boxed{\text{SELECT1}}$ the user can adjust the size of Window 1 by moving the mouse on the reflective pad. After then pressing $\boxed{\text{SELECT2}}$ the user can adjust the position of the window by moving the mouse. The user can return to adjusting the size with $\boxed{\text{SELECT1}}$ and the position with $\boxed{\text{SELECT2}}$ as many times as necessary. $\boxed{\text{ESCAPE}}$ returns to the Statistics menu.

- **SET WINDOW2** - This allows the user to adjust the size and position of Window 2, and the function of the keys is exactly the same as for SET WINDOW1.

- **CALCULATE** - This calculates, and displays near the bottom right hand corner of the display: the location and size in X and Y of the window selected with one of the SET WINDOW options or the WINDOW USE option; and the mean, maximum, minimum and standard deviation of all the pixel values within that window. It leaves the user in the Statistics menu.

- **PIXEL** - After selecting this function with [SELECT1] the user can move the cursor around in the image display area, and read out individual pixel values with [SELECT1]. [SELECT2] toggles between a zoomed and unzoomed display. [ESCAPE] returns to the unzoomed display and returns the user to the Statistics menu.

- **X-CUT** - This option collapses the selected window onto the X-axis, and plots the result. For IPCS data it sums the pixels in Y, and for CCD data it averages them. If the WINDOW1–WINDOW2 option is selected with WINDOW USE then the left and right boundaries of WINDOW2 will be changed to match those of WINDOW1, and the data from WINDOW2 will be scaled by the ratio of the window widths before subtraction. The plot will remain displayed until [ESCAPE] is pressed, when the user will be returned to the Statistics menu.

- **Y-CUT** - This option collapses the selected window onto the Y-axis, and plots the result. For IPCS data it sums the pixels in X, and for CCD data it averages them. If the WINDOW1–WINDOW2 option is selected with WINDOW USE then the upper and lower boundaries of WINDOW2 will be changed to match those of WINDOW1, and the data from WINDOW2 will be scaled by the ratio of the window widths before subtraction. The plot will remain displayed until [ESCAPE] is pressed, when the user will be returned to the Statistics menu.

- **Z-CUT** - This option is not applicable to any of the current ISIS data taking modes.

- **WINDOW USE** - This option selects the window to which X-CUT, Y-CUT or CALCULATE will be applied. After selecting this option with [SELECT1] further presses of [SELECT1] will cycle between: WINDOW1; WINDOW2; and WINDOW1–WINDOW2. The current selection is displayed just below the menu. [ESCAPE] returns the user to the Statistics menu.

9.2.4 The Screens Menu

The Screens menu allows the user to determine which data buffer is displayed in the image area, and how the data is displayed. In each case the mapping between the data buffer and the image display is such that the whole data buffer is displayed. For windowed CCD data the window is displayed in its correct position on the chip. For all CCD data the aspect ratio of the detector is preserved. Options, which can be selected with $\boxed{\text{SELECT1}}$, are:–

- **CCDS** - Data from one of the CCDs is displayed. Individual CCDs can be selected using the icons alongside the main display area.
- **IPCS 8:1** - This option has not been implemented.
- **IPCS 1:1** - The IPCS data buffer is selected. The whole display is not necessarily used in the vertical direction, and for the IPCS the pixels do not necessarily have the correct aspect ratio on the screen.

The remaining screens are not used for displaying ISIS data.

Part VII
APPENDICES

A Standard Star Fields for Photometric Calibration

A.1 Landolt Faint Star Catalogue

The first source of photometric standard stars is the Landolt faint star catalogue (1992, AJ, 104, 340), which contains over 500 stars centered on the celestial equator with UBVRI photoelectric observations. The majority of Landolt stars have $11.5 < V < 16.0$ and $-0.3 < (B-V) < 2.3$. Data (positions, magnitudes, and colors) and finding charts for this catalogue can be found in two green binders in the WHT control room. This catalogue has also been loaded into the WHT system computer, and can be accessed automatically by typing `GOCAT` followed by the object name (e.g. 92-309). The UBV photometry is tied to the Johnson & Morgan (1953) system, while the RI photometry is based on the Cousins (1976) system, which was derived from the Kron et al (1953) data. Some of these fields contain several stars which will all fit in the WHT prime focus field.

A few words of warning are in order. First, many of the Landolt stars have only been observed once or twice, and may not be suitable for very high-precision photometry. Second, some of these stars have large proper motions; proper motions where known are given in the green binder. Finally, only the faintest Landolt standards should be used ($14 \leq V \leq 16$) at the WHT prime focus, since stars brighter than this will saturate in only a few seconds, especially in R and I.

A.2 L. Davis Cluster Sequences

A.2.1 Introduction

The second source of photometric standards available at the WHT are the unpublished cluster sequences of L. Davis (NOAO). These are sequences of 20–30 stars near galactic clusters, with typically $15 \leq V \leq 20$ and $0.5 \leq (B-V) \leq 1.5$, taken at the 0.9m Kitt Peak telescope. These fields are approximately 4.6 x 7 arcmin in size, and will thus fit within the 7.2 arcmin field of the TEK2 chip at prime focus. Since the stars in these fields are generally fainter than the Landolt standards, they can be used with longer exposure times. However, observers should restrict themselves to stars brighter than V $\sim$ 18.5, as the photometric errors increase rapidly for stars fainter than this. Observers are reminded that these are *unpublished* data and are available on a user-risk basis. Because of the limited color coverage and small number of repeat observations for some field/filter combinations, observers should not rely solely on these standards, but should supplement with other standards, e.g. the Landolt standards described above (in particular, there are few blue stars [(B$-$V) $\leq$ 0.5] in these cluster sequences). Finder charts and data for these sequences are given in the next section below, and may also be found in the above-mentioned green binders.

A.2.2 Data and Finder Charts

Tables 9 – 14 below give the positions, V magnitudes and colours for the 6 Davis sequences, while Figures 9–14 are the corresponding finder charts.

B Filters

This Appendix summarises the filters available for WHT imaging. Table **??** lists the filters available for CCD imaging. All of these filters can also be used at the other ING imaging instruments: JKT Cass, INT Prime, and WHT AUX port. Information regarding the larger, circular, filters available for imaging and for Fabry-Perot spectroscopy with TAURUS-2 on the WHT can be found in the La Palma User's Guide. The information in this document comes from various sources: the La Palma Technical Notes 45, 73, 75 and 90, the INT Prime Focus manual, and a List of Optical Components compiled by Chris Benn. All of the information (filter curves and tables as available) can be found on the La Palma xmosaic server under *filters.*

Our collection consists of broad band and narrow band filters. For broad band imaging we have several sets of BVRI filters, which are not meant to leave their telescope. Our set of narrow band filters at the moment is still rather limited, except for (redshifted) Hα filters, of which we have more than 15. All filters are square, and have a length and width of more or less 50mm. Some of the larger filters do not fit into every filterwheel. There are however filterwheels to accommodate each filter.

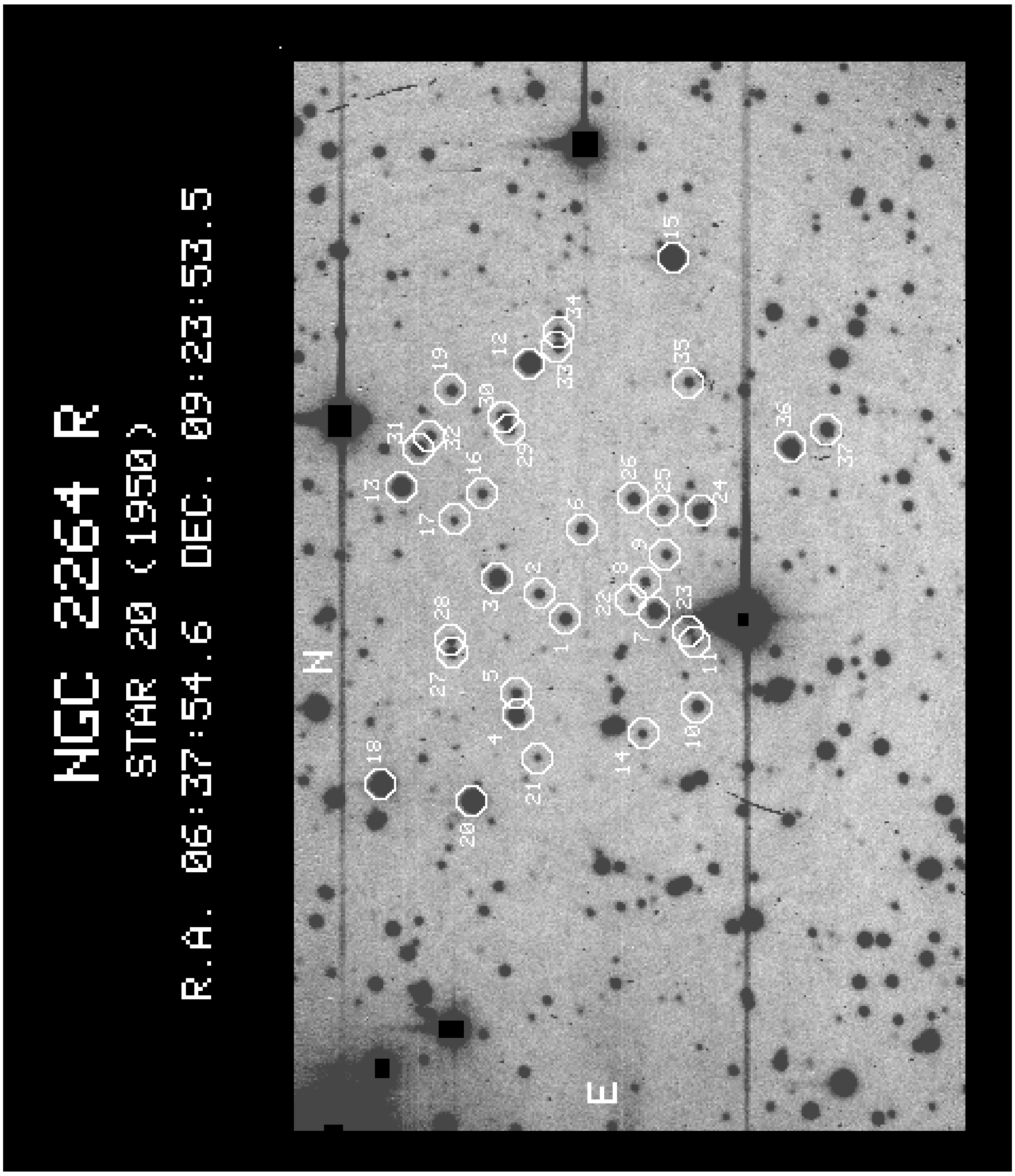


Figure 9: NGC 2264 Standard Field
[NGC 2264 Standard Photometric Field from L. Davis. The field orientation and 1950 coordinates for Star 20 are given. For all of the Davis finder charts, the field size is approximately 4.6 x 7 arcmin.]

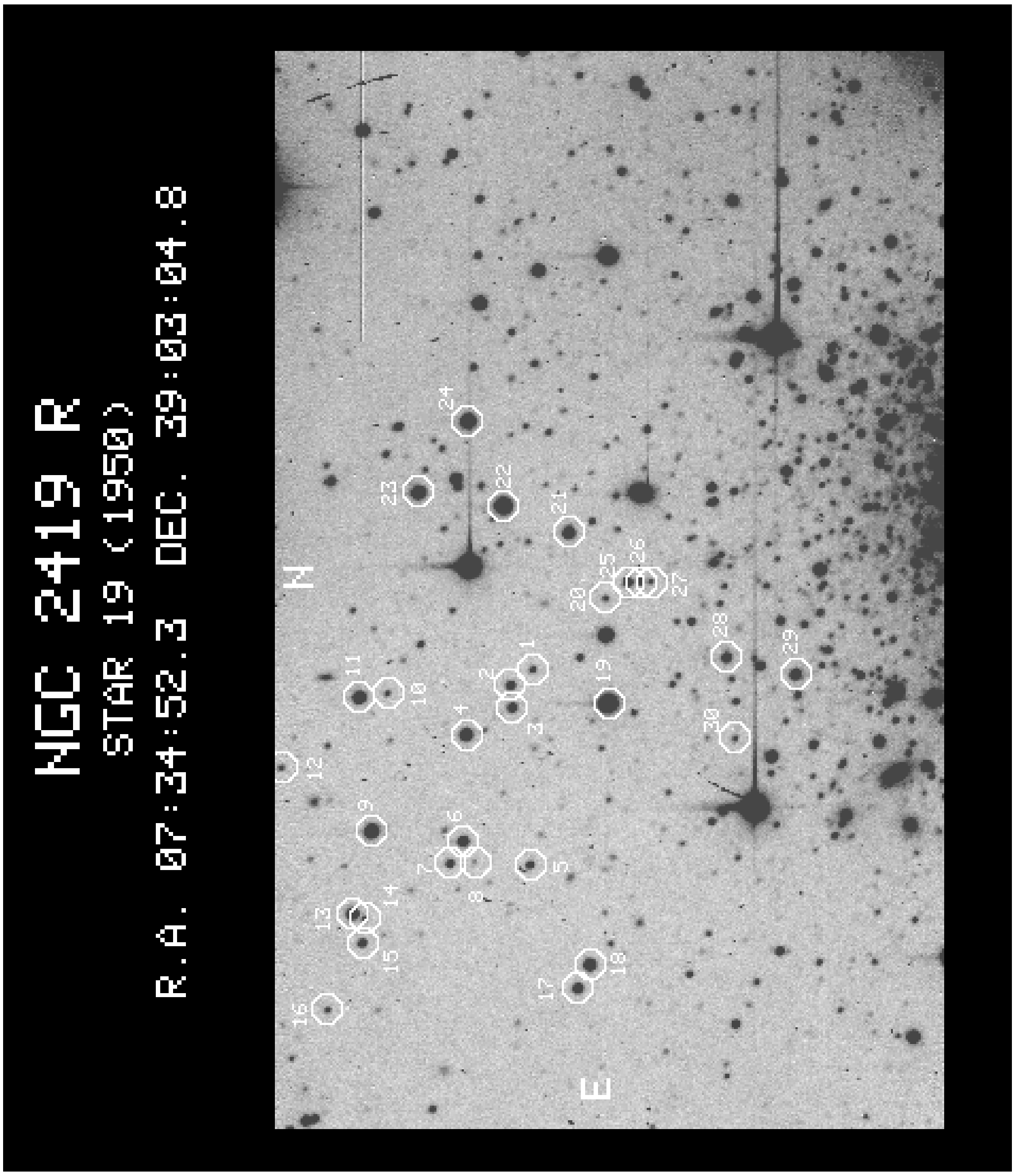


Figure 10: NGC 2419 Standard Field
[NGC 2419 Standard Photometric Field from L. Davis. The field orientation and 1950 coordinates for Star 19 are given]

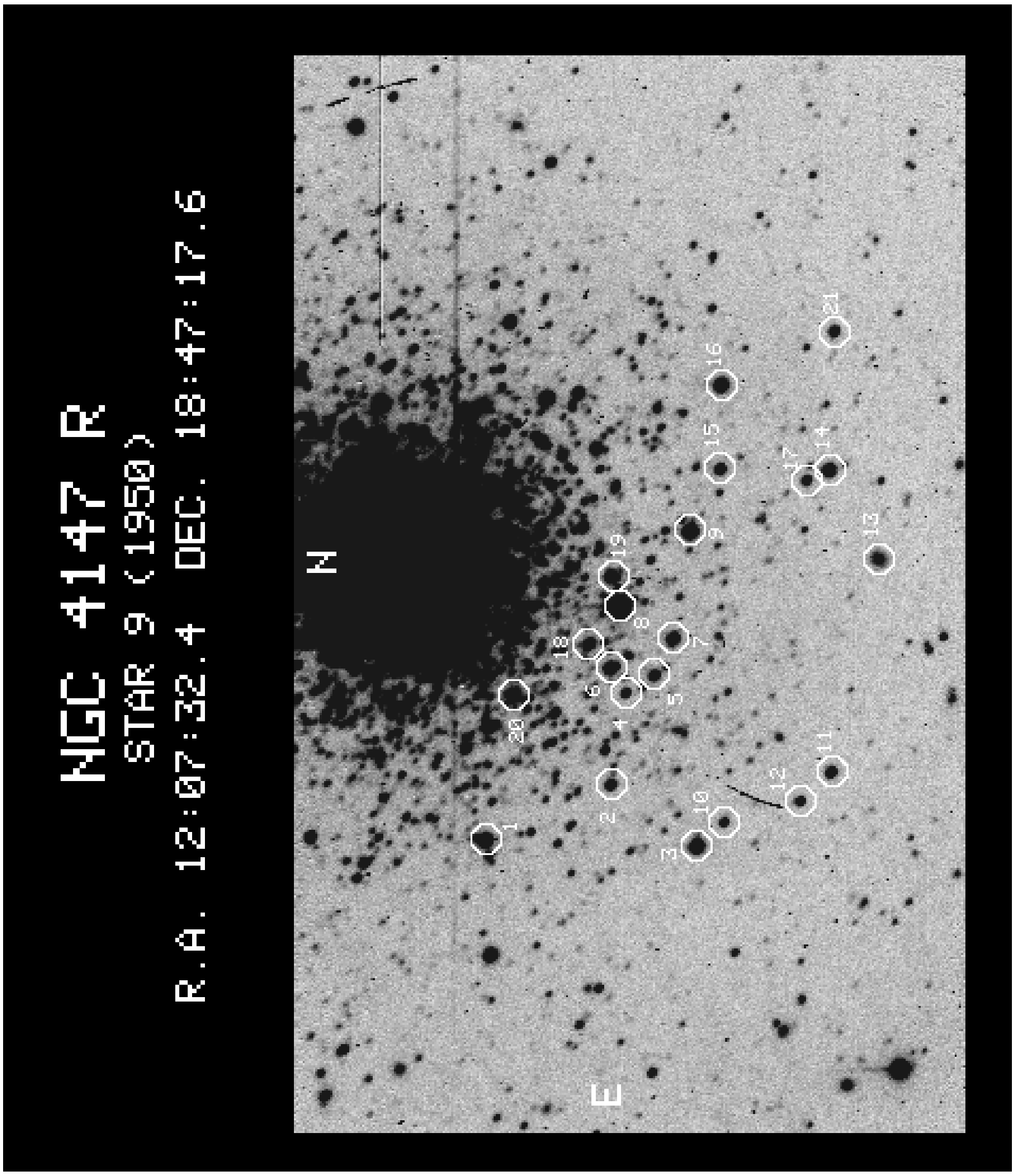


Figure 11: NGC 4147 Standard Field
[NGC 4147 Standard Photometric Field from L. Davis. The field orientation and 1950 coordinates for Star 9 are given]

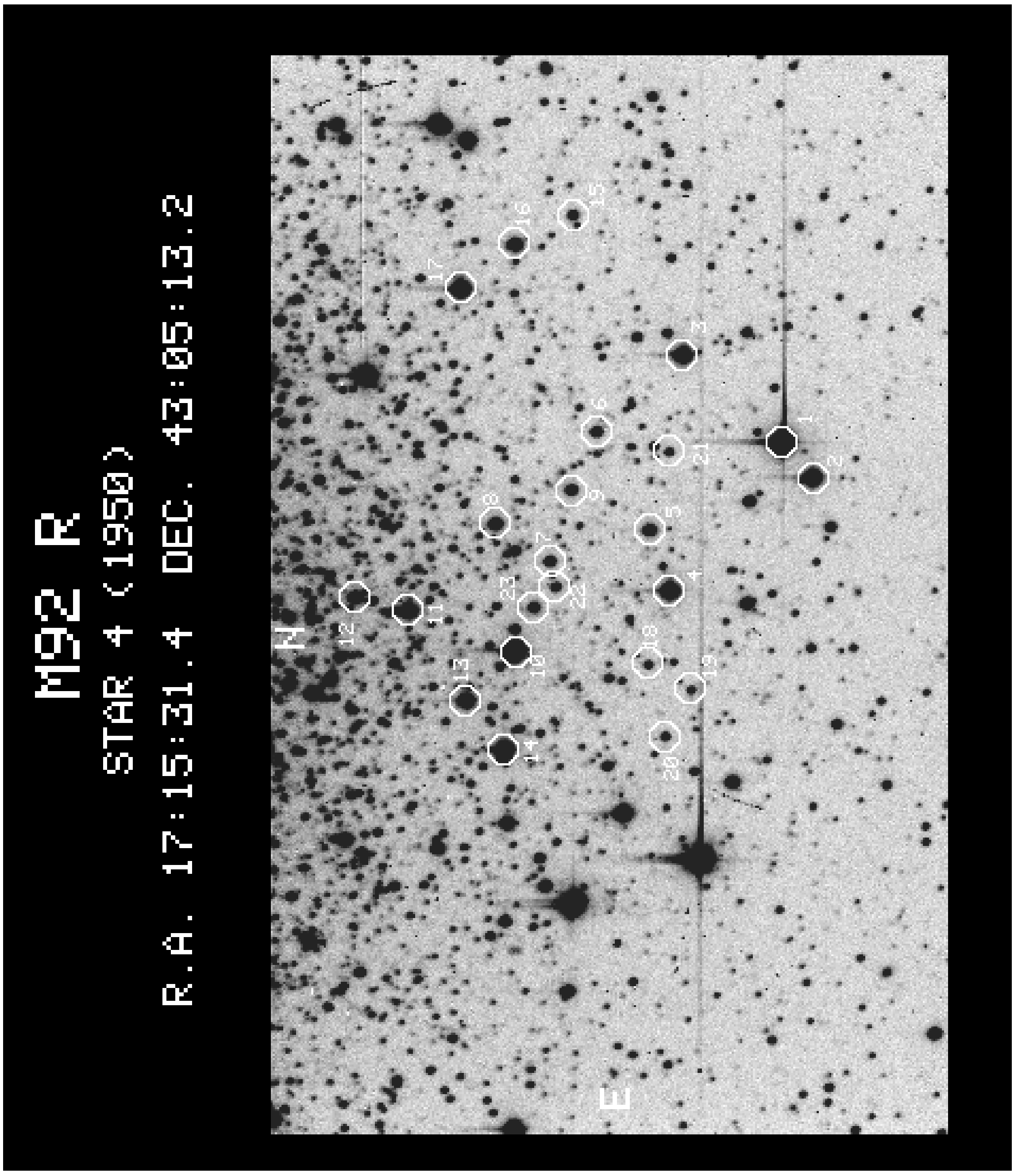


Figure 12: M92 Standard Field
[M92 Standard Photometric Field from L. Davis. The field orientation and 1950 coordinates for Star 4 are given]

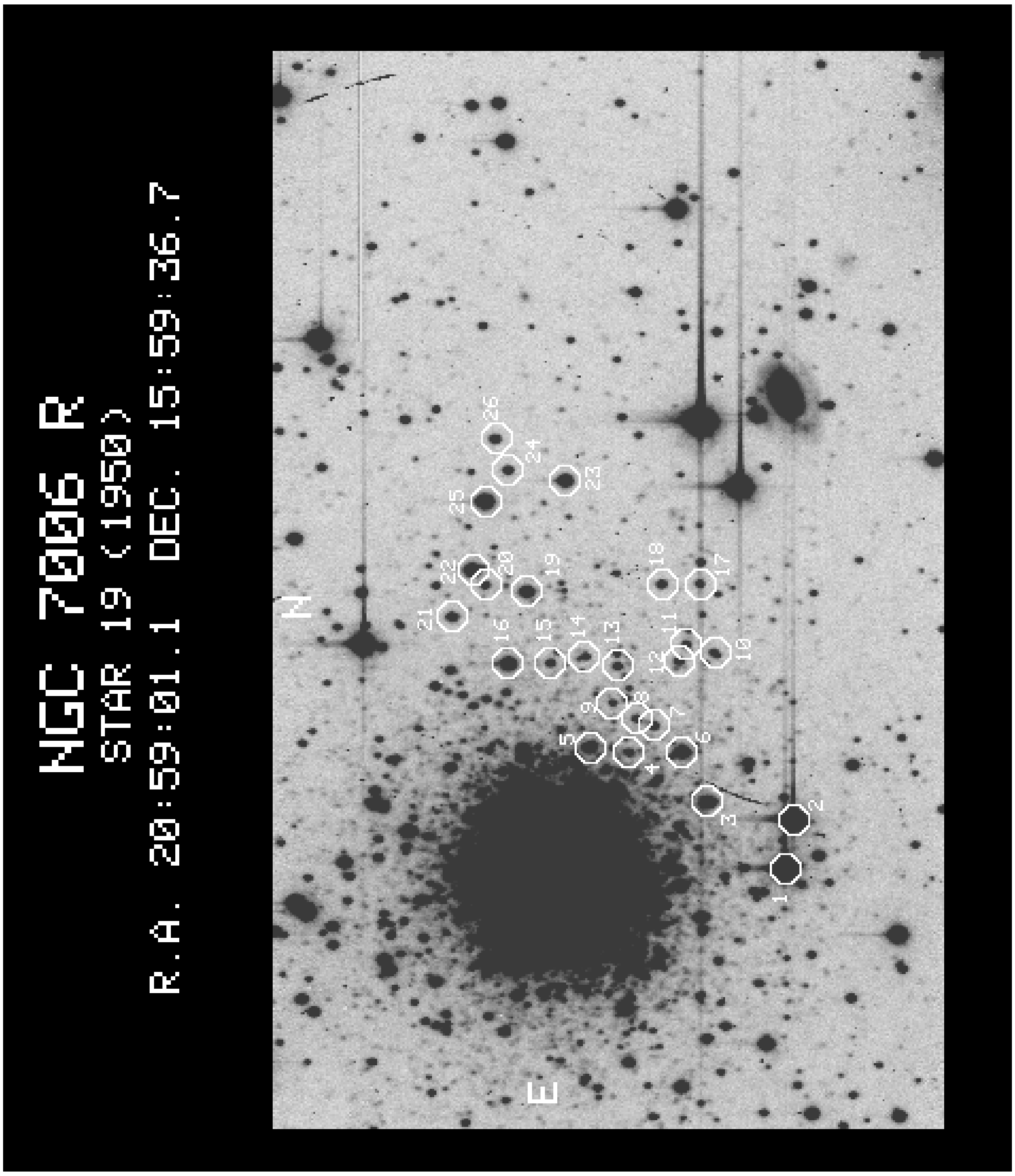


Figure 13: NGC 7006 Standard Field
[NGC 7006 Standard Photometric Field from L. Davis. The field orientation and 1950 coordinates for Star 19 are given]

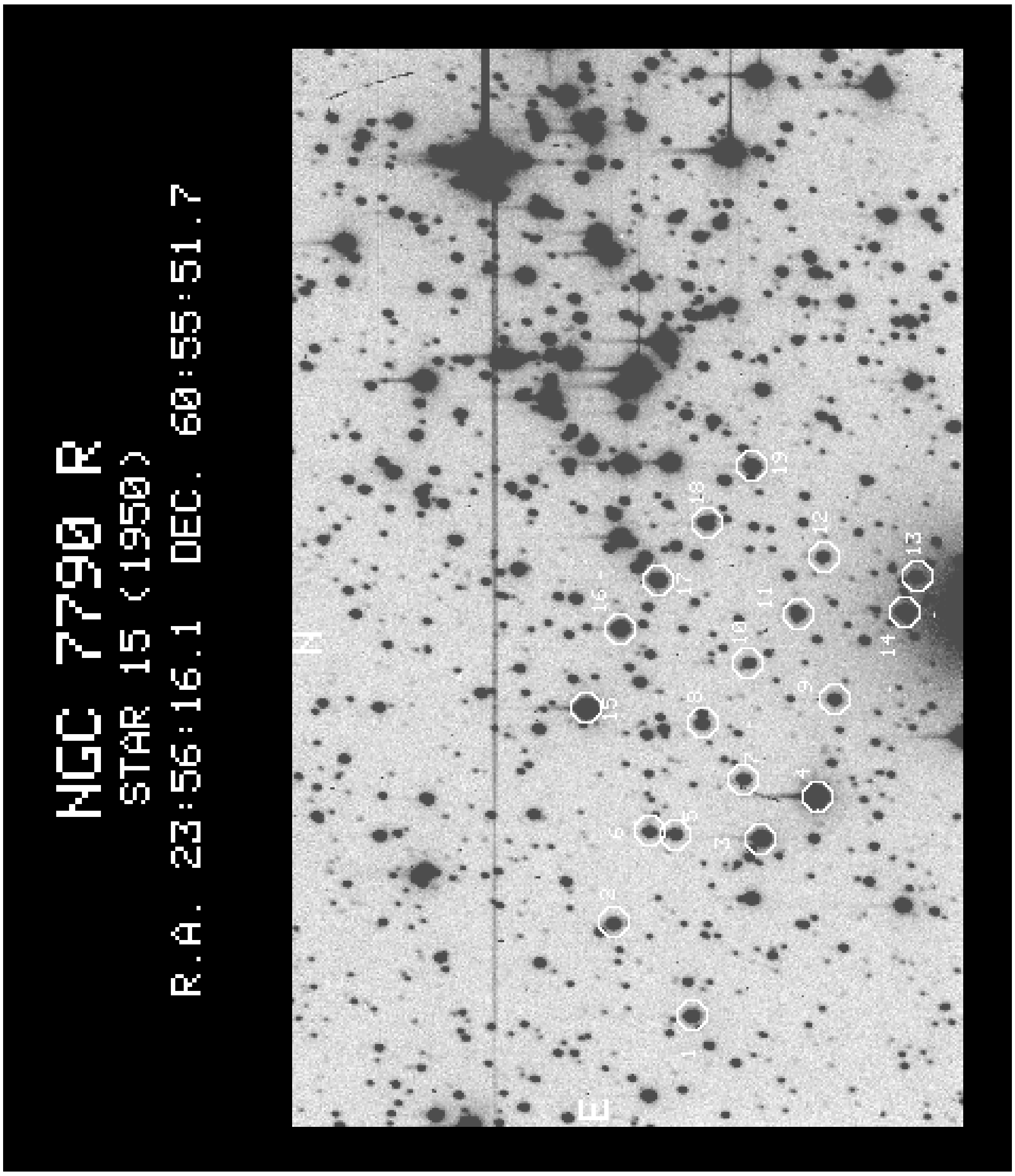


Figure 14: NGC 7790 Standard Field
[NGC 7790 Standard Photometric Field from L. Davis. The field orientation and 1950 coordinates for Star 15 are given]

Table 9: M92 Photometry from L. Davis. N is the number of observations at the given magnitude or colour.

Star	V ± N	U−B ± N	B−V ± N	V−R ± N	R−I ± N
M92-1	13.078	0.020	0.612	0.257	0.421
	0.012	0.008	0.016	0.060	0.119
	6	3	5	4	2
M92-2	14.579	0.109	0.800	0.485	0.461
	0.014	0.025	0.021	0.009	0.033
	6	3	5	4	2
M92-3	14.694	0.093	0.788	0.485	0.454
	0.019	0.017	0.033	0.017	0.018
	6	3	5	4	2
M92-4	14.618	0.111	0.783	0.486	0.464
	0.014	0.018	0.019	0.014	0.035
	6	3	5	4	2
M92-5	16.052	-0.111	0.534	0.313	0.277
	0.009	0.013	0.016	0.008	0.005
	6	3	5	4	2
M92-6	16.331	-0.442	-0.112	-0.038	-0.085
	0.021	0.012	0.018	0.010	0.005
	6	3	5	4	2
M92-7	16.437	-0.478	-0.112	-0.041	-0.086
	0.020	0.004	0.016	0.010	0.020
	6	3	5	4	2
M92-8	15.932	-0.079	0.574	0.351	0.302
	0.021	0.009	0.030	0.015	0.019
	6	3	5	4	2
M92-9	16.986	1.124	1.146	0.722	0.589
	0.010	0.044	0.012	0.008	0.029
	6	3	5	4	2
M92-10	14.036	0.325	0.798	0.516	0.417
	0.010	0.029	0.026	0.014	0.014
	6	3	5	4	2
M92-11	15.146	0.844	1.025	0.630	0.522
	0.023	0.030	0.018	0.020	0.019
	6	3	5	4	2
M92-12	15.982	-0.026	0.637	0.433	0.411
	0.027	0.014	0.072	0.013	0.013
	6	3	5	4	2
M92-13	15.078	0.067	0.589	0.360	0.321
	0.018	0.033	0.022	0.015	0.019
	6	3	5	4	2
M92-14	14.311	0.068	0.590	0.372	0.289
	0.011	0.005	0.030	0.006	0.001
	6	3	5	4	2
M92-15	17.153	-0.129	0.629	0.396	0.361
	0.009	0.004	0.029	0.019	0.015
	6	3	5	4	2
M92-16	15.264	0.061	0.107	0.058	0.049
	0.018	0.020	0.034	0.017	0.005
	6	3	5	4	2
M92-17	14.475	-0.015	0.567	0.403	0.362
	0.000	0.044	0.028	0.016	0.030
	6	3	5	4	2
M92-18	17.966	-0.247	0.488	0.320	0.320
	0.012	0.061	0.027	0.005	0.007
	6	3	5	4	2
M92-19	18.211	-0.317	0.415	0.286	0.273
	0.017	0.214	0.018	0.018	0.008
	6	3	5	4	2
M92-20	18.047	0.683	0.878	0.494	0.458
	0.041	0.070	0.029	0.047	0.007
	6	3	5	4	2
M92-21	17.925	-0.188	0.497	0.340	0.296
	0.009	0.014	0.007	0.009	0.014
	6	3	5	4	2
M92-22	17.542	-0.254	0.550	0.357	0.323
	0.015	0.039	0.017	0.017	0.020
	6	3	5	4	2
M92-23	16.791	-0.132	0.636	0.403	0.368
	0.023	0.017	0.015	0.006	0.043
	6	3	5	4	2

Table 10: NGC 7006 Photometry from L. Davis. N is the number of observations at the given magnitude or colour.

Star	V ± N	U−B ± N	B−V ± N	V−R ± N	R−I ± N
7006- 1	14.000	0.000	1.100	0.583	0.572
	0.014	0.000	0.037	0.031	0.000
	2	0	2	2	1
7006- 2	13.889	0.000	0.836	0.450	0.417
	0.017	0.000	0.030	0.032	0.000
	2	0	2	2	1
7006- 3	16.798	0.806	1.211	0.658	0.656
	0.012	0.187	0.022	0.010	0.003
	5	2	5	4	2
7006- 4	18.782	0.008	0.630	0.438	0.423
	0.009	0.144	0.027	0.028	0.035
	5	2	5	4	2
7006- 5	17.506	0.541	1.020	0.558	0.604
	0.015	0.075	0.017	0.006	0.007
	5	2	5	4	2
7006- 6	16.585	0.979	1.269	0.668	0.687
	0.011	0.009	0.020	0.017	0.010
	5	2	5	4	2
7006- 7	18.573	0.338	0.894	0.526	0.544
	0.014	0.143	0.042	0.025	0.049
	5	2	5	4	2
7006- 8	18.892	0.336	0.851	0.499	0.540
	0.039	0.234	0.048	0.037	0.059
	5	2	5	4	2
7006- 9	19.045	0.069	0.091	-0.005	0.002
	0.051	0.011	0.069	0.069	0.117
	5	2	5	4	2
7006-10	18.780	0.017	0.575	0.426	0.295
	0.026	0.030	0.043	0.085	0.032
	5	2	5	4	2
7006-11	18.838	-0.032	0.561	0.404	0.434
	0.026	0.063	0.042	0.048	0.001
	5	2	5	4	2
7006-12	18.469	0.215	0.867	0.485	0.521
	0.022	0.058	0.015	0.014	0.024
	5	2	5	4	2
7006-13	18.733	0.014	0.720	0.408	0.444
	0.030	0.124	0.048	0.014	0.010
	5	2	5	4	2
7006-14	18.837	0.020	0.646	0.370	0.411
	0.025	0.074	0.032	0.022	0.008
	5	2	5	4	2
7006-15	18.817	-0.016	0.541	0.370	0.420
	0.042	0.059	0.029	0.027	0.033
	5	2	5	4	2
7006-16	16.140	0.367	0.836	0.448	0.443
	0.015	0.051	0.013	0.013	0.003
	5	2	5	4	2
7006-17	18.820	0.316	1.034	0.391	0.547
	0.108	0.000	0.114	0.086	0.000
	4	1	4	3	1
7006-18	18.327	0.043	0.741	0.432	0.449
	0.024	0.089	0.030	0.021	0.001
	5	2	5	4	2
7006-19	16.765	0.569	0.940	0.547	0.512
	0.016	0.025	0.012	0.011	0.013
	5	2	5	4	2
7006-20	18.689	0.044	0.699	0.421	0.450
	0.021	0.016	0.057	0.041	0.000
	5	2	5	4	2
7006-21	17.909	0.456	0.972	0.526	0.560
	0.011	0.063	0.026	0.007	0.025
	5	2	5	4	2
7006-22	16.479	1.210	1.281	0.781	0.710
	0.020	0.049	0.023	0.019	0.004
	5	2	5	4	2
7006-23	16.484	0.353	0.821	0.459	0.452
	0.015	0.030	0.010	0.010	0.004
	5	2	5	4	2
7006-24	18.265	0.188	0.788	0.467	0.497
	0.015	0.146	0.024	0.017	0.027
	5	2	5	4	2
7006-25	15.518	0.094	0.680	0.358	0.376
	0.012	0.042	0.010	0.018	0.000
	5	2	5	2	1
7006-26	18.124	0.415	1.001	0.591	0.531
	0.012	0.370	0.025	0.013	0.012
	5	2	5	4	2

Table 11: NGC 7790 Photometry from L. Davis. N is the number of observations at the given magnitude or colour.

Star	V	U−B	B−V	V−R	R−I
	±	±	±	±	±
	N	N	N	N	N
7790- 1	14.862	-0.027	0.541	0.294	0.381
	0.011	0.007	0.007	0.001	0.000
	2	2	2	2	1
7790- 2	15.216	0.169	0.592	0.299	0.409
	0.006	0.020	0.024	0.002	0.000
	5	5	5	2	1
7790- 3	14.149	0.204	0.836	0.465	0.503
	0.021	0.016	0.000	0.004	0.000
	2	2	2	2	1
7790- 4	13.208	1.336	1.518	0.634	0.000
	0.028	0.011	0.013	0.000	0.000
	2	2	2	1	0
7790- 5	15.745	0.338	0.761	0.399	0.517
	0.006	0.023	0.027	0.009	0.004
	5	5	5	5	3
7790- 6	15.778	0.295	0.643	0.328	0.488
	0.012	0.025	0.022	0.008	0.009
	5	5	5	5	3
7790- 7	15.753	0.445	1.047	0.567	0.590
	0.009	0.040	0.022	0.011	0.031
	5	5	5	5	3
7790- 8	15.503	0.102	0.706	0.399	0.499
	0.010	0.029	0.022	0.012	0.001
	5	5	5	5	3
7790- 9	15.585	0.260	0.599	0.299	0.405
	0.004	0.036	0.027	0.011	0.007
	5	5	5	5	3
7790-10	15.954	0.344	0.772	0.421	0.547
	0.011	0.037	0.032	0.011	0.005
	5	5	5	5	3
7790-11	15.315	0.291	0.646	0.339	0.445
	0.015	0.040	0.031	0.002	0.010
	5	5	5	4	2
7790-12	15.924	0.299	0.619	0.311	0.421
	0.010	0.035	0.028	0.007	0.005
	5	5	5	5	3
7790-13	15.950	0.403	0.795	0.413	0.516
	0.013	0.004	0.015	0.006	0.000
	3	3	3	3	1
7790-14	15.365	1.150	1.750	0.960	0.000
	0.008	0.239	0.046	0.000	0.000
	3	3	3	1	0
7790-15	13.156	0.255	0.540	0.000	0.000
	0.006	0.000	0.006	0.000	0.000
	2	2	2	0	0
7790-16	14.231	-0.340	0.595	0.330	0.432
	0.022	0.040	0.008	0.007	0.000
	2	2	2	2	1
7790-17	14.389	-0.007	0.461	0.249	0.345
	0.023	0.007	0.009	0.003	0.000
	2	2	2	2	1
7790-18	14.722	0.047	0.494	0.283	0.375
	0.028	0.004	0.011	0.001	0.000
	2	2	2	2	1
7790-19	14.525	0.016	0.514	0.289	0.384
	0.026	0.001	0.018	0.004	0.000
	2	2	2	2	1

Table 12: NGC 2264 Photometry from L. Davis. N is the number of observations at the given magnitude or colour.

Star	V	U−B	B−V	V−R	R−I
	±	±	±	±	±
	N	N	N	N	N
2264- 1	19.102	0.784	1.543	0.857	0.909
	0.000	0.000	0.000	0.052	0.010
	2	1	1	2	2
2264- 2	20.018	2.354	1.607	0.939	1.114
	0.041	0.000	0.000	0.030	0.065
	2	1	1	2	2
2264- 3	17.635	0.435	1.326	0.776	0.826
	0.008	0.000	0.000	0.000	0.001
	2	1	1	2	2
2264- 4	17.623	0.808	1.200	0.671	0.778
	0.000	0.000	0.000	0.018	0.003
	2	1	1	2	2
2264- 5	19.965	1.047	1.477	1.011	0.898
	0.026	0.000	0.000	0.018	0.023
	2	1	1	2	2
2264- 6	19.157	-0.591	1.461	0.666	0.944
	0.105	0.000	0.000	0.111	0.069
	2	1	1	2	2
2264- 7	18.238	0.428	1.065	0.674	0.774
	0.037	0.000	0.000	0.035	0.016
	2	1	1	2	2
2264- 8	20.354	-0.344	0.142	1.083	0.897
	0.061	0.000	0.000	0.133	0.148
	2	1	1	2	2
2264- 9	20.097	0.157	1.809	0.743	0.961
	0.055	0.000	0.000	0.098	0.031
	2	1	1	2	2
2264-10	19.169	0.009	1.478	0.759	0.900
	0.000	0.000	0.000	0.019	0.075
	2	1	1	2	2
2264-11	20.340	0.000	1.292	1.024	0.757
	0.329	0.000	0.000	0.259	0.141
	2	0	1	2	2
2264-12	16.709	0.912	1.566	0.961	1.035
	0.011	0.000	0.000	0.008	0.012
	2	1	1	2	2
2264-13	17.101	0.781	1.206	0.700	0.783
	0.011	0.000	0.000	0.021	0.004
	2	1	1	2	2
2264-14	20.349	1.746	2.267	0.834	1.255
	0.000	0.000	0.000	0.066	0.076
	2	1	1	2	2
2264-15	15.807	0.833	1.427	0.865	0.987
	0.043	0.000	0.000	0.000	0.000
	2	1	1	1	1
2264-16	20.240	0.000	1.441	0.952	0.991
	0.000	0.000	0.000	0.045	0.187
	2	0	1	2	2
2264-17	20.822	-1.471	2.248	0.877	0.954
	0.294	0.000	0.000	0.513	0.120
	2	1	1	2	2
2264-18	15.413	0.403	0.930	0.541	0.462
	0.015	0.000	0.000	0.000	0.000
	2	1	1	1	1
2264-19	19.812	1.109	1.642	0.991	1.104
	0.008	0.000	0.000	0.007	0.180
	2	1	1	2	2
2264-20	15.765	0.714	1.092	0.598	0.689
	0.000	0.000	0.000	0.000	0.000
	2	1	1	1	1
2264-21	21.201	-0.009	0.951	1.141	1.339
	0.159	0.000	0.000	0.099	0.037
	2	1	1	2	2
2264-22	20.844	0.000	0.000	0.442	1.159
	0.929	0.000	0.000	1.062	0.017
	2	0	0	2	2
2264-23	19.997	0.000	0.108	0.735	0.892
	0.152	0.000	0.000	0.061	0.008
	2	0	1	2	2
2264-24	18.056	1.0[illegible]5	1.336	0.811	0.894
	0.000	0.000	0.000	0.016	0.001
	2	1	1	2	2
2264-25	19.747	1.152	1.338	0.944	0.909
	0.046	0.000	0.000	0.044	0.013
	2	1	1	2	2
2264-26	19.089	0.307	1.529	0.913	0.919
	0.000	0.000	0.000	0.052	0.043
	2	1	1	2	2
2264-27	19.645	0.000	1.413	1.060	1.016
	0.066	0.000	0.000	0.024	0.074
	2	0	1	2	2
2264-28	19.972	0.933	1.464	0.790	1.046
	0.668	0.000	0.000	0.383	0.161
	2	1	1	2	2
2264-29	19.584	0.000	1.602	1.056	1.084
	0.397	0.000	0.000	0.056	0.026
	2	0	1	2	2
2264-30	18.502	1.893	1.680	0.971	1.032
	0.023	0.000	0.000	0.010	0.016
	2	1	1	2	2
2264-31	18.312	0.957	1.495	0.881	0.905
	0.025	0.000	0.000	0.003	0.007
	2	1	1	2	2
2264-32	19.595	0.666	1.508	0.839	1.011
	0.016	0.000	0.000	0.033	0.066
	2	1	1	2	2
2264-33	19.485	0.000	1.616	0.988	1.155
	0.027	0.000	0.000	0.087	0.068
	2	0	1	2	2
2264-34	19.791	0.000	1.466	1.067	1.121
	0.045	0.000	0.000	0.028	0.038
	2	0	1	2	2
2264-35	20.030	0.706	1.565	0.997	1.546
	0.030	0.000	0.000	0.053	0.004
	2	1	1	2	2
2264-36	17.490	0.737	1.469	0.937	1.252
	0.054	0.000	0.000	0.017	0.033
	2	1	1	2	2
2264-37	18.536	0.469	1.296	0.801	0.799
	0.023	0.000	0.000	0.045	0.100
	2	1	1	2	2

Table 13: NGC 2419 Photometry from L. Davis. N is the number of observations at the given magnitude or colour.

Star	V ± N	U−B ± N	B−V ± N	V−R ± N	R−I ± N
2419- 1	20.250	0.108	0.835	0.534	0.408
	0.021	0.391	0.064	0.087	0.257
	4	4	4	4	4
2419- 2	19.063	-0.344	0.461	0.307	0.345
	0.023	0.230	0.037	0.011	0.071
	4	4	4	4	4
2419- 3	18.986	0.324	0.963	0.576	0.613
	0.013	0.172	0.016	0.012	0.044
	4	4	4	4	4
2419- 4	18.034	1.249	1.633	0.938	1.238
	0.023	0.254	0.029	0.036	0.035
	4	4	4	4	4
2419- 5	19.676	-0.026	0.590	0.375	0.434
	0.011	0.382	0.033	0.014	0.048
	4	4	4	4	4
2419- 6	18.472	0.493	1.066	0.596	0.612
	0.020	0.153	0.019	0.014	0.018
	4	4	4	4	4
2419- 7	19.485	-0.066	0.615	0.374	0.245
	0.022	0.157	0.044	0.035	0.161
	4	4	4	4	4
2419- 8	21.229	-0.295	-0.046	-0.071	-0.920
	0.109	0.258	0.129	0.136	0.642
	4	4	4	4	4
2419- 9	16.871	-0.054	0.580	0.356	0.372
	0.014	0.074	0.010	0.009	0.043
	4	4	4	4	4
2419-10	20.410	0.287	0.237	0.114	0.153
	0.046	0.299	0.086	0.049	0.189
	4	4	4	4	4
2419-11	17.688	0.939	1.095	0.643	0.548
	0.000	0.151	0.014	0.012	0.031
	4	4	4	4	4
2419-12	20.641	0.021	0.093	0.089	0.252
	0.064	0.140	0.074	0.080	0.349
	4	4	4	4	4
2419-13	17.549	-0.045	0.420	0.270	0.264
	0.017	0.071	0.014	0.009	0.013
	4	4	4	4	4
2419-14	18.889	-0.325	0.368	0.186	0.262
	1.547	0.585	0.083	0.096	0.015
	4	4	4	4	4
2419-15	19.650	0.720	1.327	0.739	0.722
	0.030	0.879	0.126	0.038	0.068
	4	3	4	4	4
2419-16	20.271	-0.088	0.402	0.273	0.314
	0.232	0.301	0.108	0.107	0.271
	4	4	4	4	4
2419-17	18.681	0.254	1.030	0.584	0.601
	0.011	0.182	0.024	0.017	0.057
	4	4	4	4	4
2419-18	17.920	0.760	1.193	0.653	0.666
	0.009	0.077	0.033	0.010	0.040
	4	4	4	4	4
2419-19	15.516	-0.044	0.572	0.359	0.370
	0.000	0.103	0.011	0.004	0.042
	4	4	4	2	2
2419-20	20.411	-0.052	0.229	0.155	0.411
	0.087	0.453	0.102	0.090	0.276
	4	4	4	4	4
2419-21	17.933	0.721	1.168	0.646	0.674
	0.009	0.103	0.016	0.015	0.051
	4	4	4	4	4
2419-22	16.061	0.050	0.658	0.382	0.373
	0.006	0.067	0.015	0.011	0.027
	4	4	4	4	4
2419-23	17.210	0.566	0.944	0.560	0.510
	0.000	0.044	0.021	0.009	0.039
	4	4	4	4	4
2419-24	16.837	0.588	0.908	0.546	0.495
	0.014	0.097	0.047	0.021	0.031
	4	4	4	4	4
2419-25	19.240	-0.005	0.872	0.441	0.583
	0.082	0.344	0.113	0.105	0.088
	4	4	4	4	4
2419-26	20.009	-0.370	0.758	0.489	0.659
	0.087	0.313	0.089	0.081	0.244
	4	4	4	4	4
2419-27	20.595	0.037	0.074	0.192	0.160
	0.062	0.228	0.055	0.223	0.505
	4	4	4	4	4
2419-28	18.802	0.411	0.937	0.576	0.597
	0.011	0.288	0.086	0.014	0.033
	4	4	4	4	4
2419-29	18.127	-0.100	0.585	0.372	0.408
	0.006	0.084	0.021	0.014	0.046
	4	4	4	4	4
2419-30	20.417	-0.104	0.291	0.138	0.167
	0.233	0.217	0.322	0.226	0.298
	4	4	4	4	4

Table 14: NGC 4147 Photometry from L. Davis. N is the number of observations at the given magnitude or colour.

Star	V ± N	U−B ± N	B−V ± N	V−R ± N	R−I ± N
4147- 1	16.824	0.193	0.807	0.476	0.468
	0.022	0.041	0.022	0.020	0.031
	7	4	6	7	6
4147- 2	18.303	0.190	0.694	0.443	0.408
	0.028	0.545	0.024	0.025	0.014
	7	4	6	7	6
4147- 3	16.773	0.199	0.828	0.477	0.475
	0.017	0.038	0.017	0.014	0.011
	7	4	6	7	6
4147- 4	18.986	-0.144	0.694	0.397	0.344
	0.058	0.486	0.079	0.050	0.084
	7	4	6	7	6
4147- 5	18.214	0.028	0.696	0.416	0.424
	0.025	0.043	0.020	0.014	0.042
	7	4	6	7	6
4147- 6	17.663	0.976	1.156	0.700	0.601
	0.025	0.090	0.022	0.022	0.017
	7	4	6	7	6
4147- 7	17.464	0.079	0.752	0.452	0.446
	0.019	0.081	0.014	0.017	0.019
	7	4	6	7	6
4147- 8	15.081	0.720	1.066	0.558	0.605
	0.018	0.018	0.008	0.045	0.026
	6	4	5	2	2
4147- 9	16.424	-0.093	0.675	0.423	0.427
	0.020	0.022	0.030	0.022	0.010
	7	4	6	7	6
4147-10	18.982	-0.151	0.692	0.416	0.394
	0.022	0.114	0.028	0.031	0.056
	7	4	6	7	6
4147-11	18.569	0.878	1.395	0.852	0.951
	0.012	0.968	0.046	0.015	0.017
	6	3	5	6	5
4147-12	18.979	-0.231	0.681	0.397	0.418
	0.015	0.234	0.032	0.030	0.046
	6	3	5	6	5
4147-13	19.774	0.008	1.430	0.728	0.773
	0.140	0.274	0.242	0.340	0.174
	5	3	5	6	5
4147-14	16.989	-0.206	0.488	0.323	0.343
	0.009	0.031	0.029	0.021	0.014
	5	3	4	5	4
4147-15	18.029	0.048	0.719	0.438	0.435
	0.008	0.143	0.024	0.016	0.016
	7	4	6	7	6
4147-16	16.891	0.102	0.713	0.409	0.388
	0.018	0.047	0.025	0.022	0.014
	7	4	6	7	6
4147-17	18.770	-0.021	0.672	0.419	0.428
	0.009	0.052	0.020	0.018	0.066
	6	3	5	6	5
4147-18	17.410	-0.059	-0.008	0.007	-0.015
	0.023	0.026	0.012	0.033	0.032
	7	4	6	7	6
4147-19	17.993	1.039	1.479	0.901	0.976
	0.047	0.375	0.058	0.031	0.026
	7	4	6	7	6
4147-20	16.780	0.121	0.103	0.083	0.083
	0.027	0.012	0.018	0.024	0.028
	7	4	6	7	6
4147-21	18.709	1.772	1.480	0.877	0.867
	0.012	1.408	0.026	0.027	0.038
	6	3	5	6	5

Table 15: Summary of filters for CCD imaging

Type	Central wavelength (nm)	Bandpass (nm)	Peak transmission (per cent)	Thickness (mm)	#	Comments
Kitt Peak broad-band glass/interference filters:						
B	440	110	80	3	3	
V	547	94	80	3	2	
V	547*	94	80	5	1	
R	646*	126	87	3	3	
I	809*	184	85	3	3	
U-band filters:						
U	360*	62	60	7	1	25mm square
U	360*	62	60	7	1	38mm square
U	360*	62	60	6	4	50mm square 1 damaged
U	360	62	$\sim$ 30	?	1	
Glass broad-band filters (Harris set):						
B	436*	107	67	4	3	
V	545*	105	88	4	3	
R	659*	149	84	4	3	
Glass broad-band filters (RGO set):						
B	435	106	52	7.3	2	
V	535	94	70	7.2	2	
R	645	150	81	7.2	2	
I	$\sim$840	$\sim$200	94	7.0	2	
Z	$\sim$930	$\sim$150	80	7.1	3	
Emission line interference filters:						
[OII]	373.1*	5.2	43	9	1	
[SII]	407.5	3.0	33	9	1	
HeII	469.1*	4.9	61	9	1	
Hβ	486.6*	5.1	60	9	1	
[OIII]	501.2*	5.0	61	9	1	
HeII	588.1	4.6	62	9	1	
[OI]	630.6*	5.3	70	9	1	Red leak
Hα	655.6*	6.0	70	8.2	1	Ghost
[NII]	659.0*	1.6	60	9	1	
[SII]	673.0	4.8	68	9	1	
[OII]	733.1	4.6	67	9	1	
[SIII]	907.5*	5.4	74	9	1	
[SIII]	953.9*	5.2	74	9	1	
HeII	1083.7*	11.4	52	9	1	

Table 15: Summary of filters for CCD imaging (continued)

Type	Central wavelength (nm)	Bandpass (nm)	Peak transmission (per cent)	Thickness (mm)	#	Comments
Redshifted Hα interference filters: - old set						
	656.3	5.3	50	6.0	1	
	660.7	5.3	54	6.0	1	
	665.2	4.9	55	7.5	1	
	670.0	5.3	58	7.5	1	
	674.2	4.7	54	7.5	1	
	678.9	5.3	60	7.5	1	
	683.5	5.0	55	6.0	1	
	687.7	5.3	58	6.0	1	
	692.5	5.0	59	6.5	1	
	697.0	5.1	57	6.0	1	
Redshifted Hα interference filters: - new set						
	656.5	4.5	56	7	1	
	656.5	6.0	53	7	1	
	659.5	4.5	51	7	1	
	662.5	4.5	56	7	1	
	665.5	4.5	56	7	1	
	668.5	4.5	56	7	1	
	671.5	4.5	56	7	1	

B.1 Broad band filters – the Kitt Peak Interference Filters (BVRI)

These were purchased from Kitt Peak, as originally specified by J Mould. They have flat-topped profiles and are intended for use with CCD detectors (unlike earlier filter systems). Figure 16 shows details of these filters. Three sets exist; two sets for the ING telescopes and a spare set at RGO. The original specifications are given below:

All filters to be 5cm × 5cm, 3mm thick, blocked to 1.1 micron, bett er than 75% peak transmission (except B 70%), MgF_2 coated, no pinholes, optical quality glass.

R: *Filter 7200Å= short-pass hard-coated on 3mm OG590, blocked to 1.1 mi cron, 75% or better peak transmission, MgF_2 coated on glass side.*

I: *Filter 9000Å= Short-pass hard-coated on 3mm RG-M9, blocked 1.1 micro n, 75% or better peak transmission, MgF_2 coated on glass side.*

V: *Filter 6000Å= Short-pass hard-coated on 3mm GG 495 blocked to 1.1 mi cron, 75% or better peak transmission, MgF_2 coated on glass side. (Sent back did not come up to specification, 1/6/81)*

B: *Filter 4900Å= Short-pass, hard-coated on the glass substrate indicat ed below, blocked to 1.1 micron, 65% or better peak transmission, MgF2 Coated on glass side. Glass substrate to be cemented combination of Schott GG 385 and either Hoya GM-500 or Hoya C-500 (whichever will adequately suppress the red leak). Total thickness to be 3mm as with the other items.*

B.2 Broad band filters – The RGO Glass Broad Band Filters (UBVRIZ)

These filters have been made at RGO from various cemented combinations of Schott glass. R W Argyle specified the combinations, which are similar to those in use at the AAT, SAAO and elsewhere. These filters are 2 inch in size, and Table B.2 shows details of these filters. Three sets exist; two sets for the ING telescopes, and one set at RGO. These filters are on the Johnson system. Nowadays, this system (for R and I) is not used very often any more, possibly because of the large sky background. At La Palma the RGO R and I are seldom used. The U,B and V filters however are not very different from U, B and V filters on other systems. See Fig 15 for the scans of these filters.

Table 16: RGO Glass Filters
RGO Glass Filters

Filter	Materials
U	1mm UG1 + 5mm $CuSO_4$ (Solid)
B	1mm GG385 +1mm BG12 + 1mm BG18 + 2mm KG3 + 2mm WG280
V	2mm GG495 + 2mm BG 18 + 2mm KG3 +1mm WG280
R	2mm KG3 + 2mm OG570 + 3mm WG280
I	3mm RG9 + 4mm WG280
Z	4mm RG850 + 3mm WG280

The WG280 is used to give uniform thickness of all filters (except U). For Z, and to some extent I, the longwave cutoff is determined by the CCD response.

B.3 Broadband filters – the Harris set (BVR)

To replace a deteriorating set of Kitt Peak filters, 3 sets of large (125 mm) BVR glass colour filters were purchased in 1990 for CCD imaging.

The filters consist of cemented stacks of Schott glass, following the recipe below (see also NOAO newsletter 11,12 and 14:

B: 2mm BG12 + 2mm BG39
V: 2mm OG570 + 2mm KG3
R: 1mm BG12 + 2mm BG39 + 1mm GG385

It is thought that

- When the filter response curves are convolved with a typical CCD response, the glass filters provide a closer match to the standard Johnson B and V and the Kron-Cousins R bandpass.
- The transmission of the glass filters is comparable to that of the interference filters, and does not deteriorate with time.
- Glass filters are significantly cheaper than interference filters of the same size.

Harris filters are very often used at La Palma, just like Kitt Peak filters, probably because both are on the Kron-Cousins system. Note that the transmission in B is significantly (about 13%) lower than in Kitt Peak B. See Figs 16 and 17 for details of these filters.

B.4 Narrow band filters

At present, we have 31 narrow band filters, mostly of 50Å bandwidth, comprising a set of emission line filters and a set of redshifted Hα redshifted filters. Only one set exists and therefore the filters are shared between the WHT, INT and JKT. These filters were specified for a focal ratio of 4.5 which explains the difference in wavelength between the actual peak wavelength and the required peak wavelength. The original specification for the emission line filters is given below:

Unless otherwise specified the effects of an f/4.5 converging beam of light has been taken into account and the central wavelength duly reddened. A correction of +2 Angstroms has also been made to correct the central wavelength for operation at +10 degrees Celsius on the assumption that the filters will be made, tested and specified at +20 degrees Celsius.

In all cases the thickness of the filter including blocking filters should not exceed 9mm and should be the same for all filters wherever possible. The effective refractive index should be near 2.1. Blocking in all cases should be 3000-12000 Angstroms and the tolerance on the central wavelength should be ± 3 Angstroms. The tolerance on the dimensions of each filter should be ± 0.5mm. Filters should be free from pinholes greater than 0.03mm diameter in the central 25mm diameter circle and free from pinholes greater than 0.1mm diameter elsewhere.

See Figures 17, 18, and 19 for details of these filters.

B.5 U Filters

Some stuff on the U filters here

B.6 General Remarks

The filters marked with an asterisk in Table B have been scanned in October, 1994. No lightleaks were found, except for the [OI] λ 6306 filter (see Fig. 18). We plan to scan the rest of the interference filters in the first half of 1995. Many filters are already old, which means in particular that their edges are not as smooth as they could be. To prevent stray light coming in through the edges, especially on INT-PF, some blocking off of the edges

Table 17: Colour terms for the TEK2 chip at Prime Focus. The Colour terms are given in the sense of (Observed − Landolt).

Filter	Filter Type	Fitted Colour	Colour Term	R.M.S.
U		(U−B)	−0.128	0.05
B		(B−V)	−0.064	0.03
V		(B−V)	−0.007	0.03
R		(V−R)	−0.029	0.03
I		(R−I)	−0.123	0.02

before observing is advisable. Finally, remember that what you measure is the transmission of the filter convolved with the CCD response (see Fig 6).

Table 17 gives the standard colour terms for the TEK2 chip at prime focus; this information can also be found in the information browsers at La Palma and Cambridge and in the LPINFO system on the Cambridge VAX GXVG. See also Section 4.8.

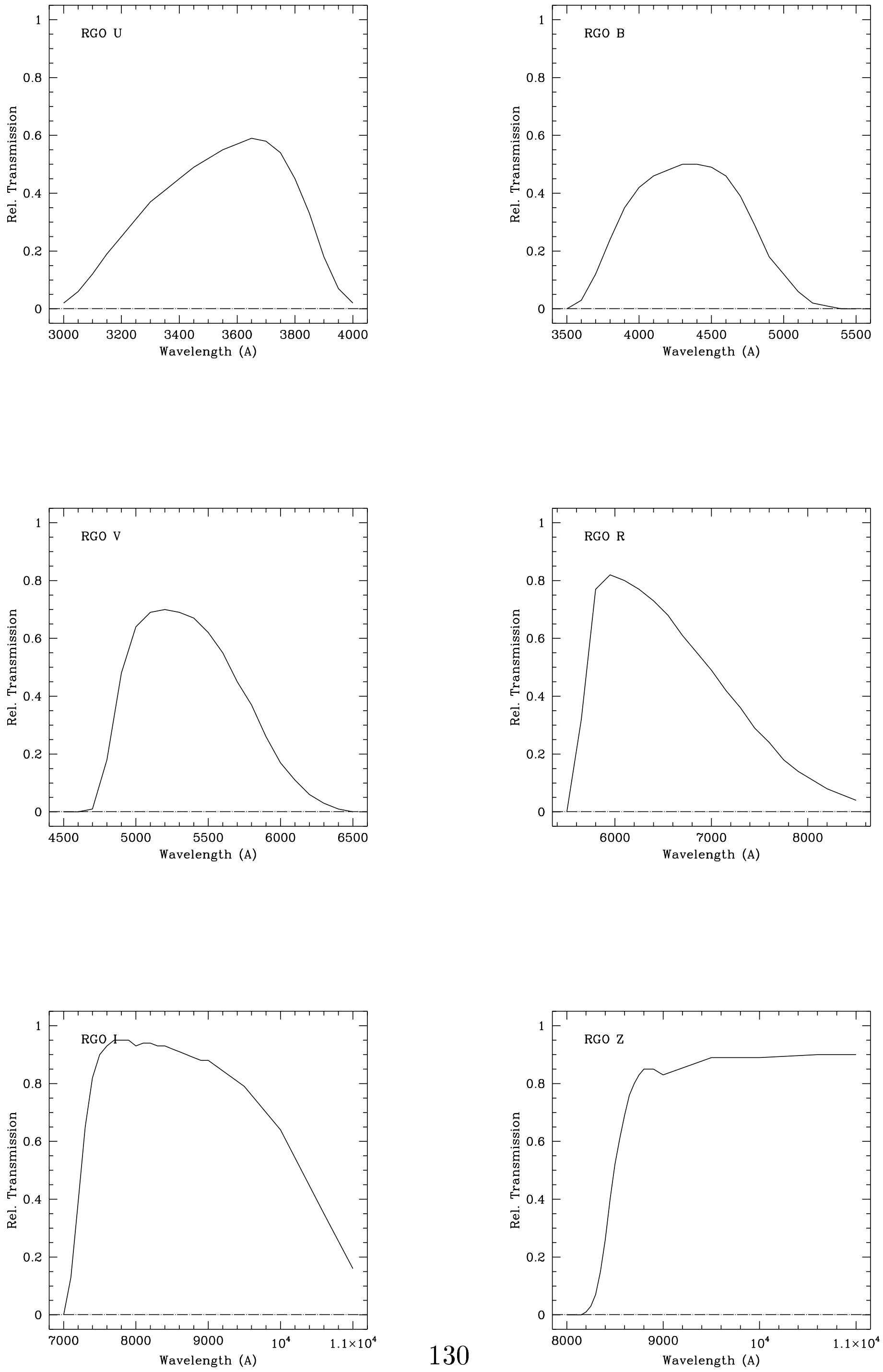


Figure 15: RGO Glass filters

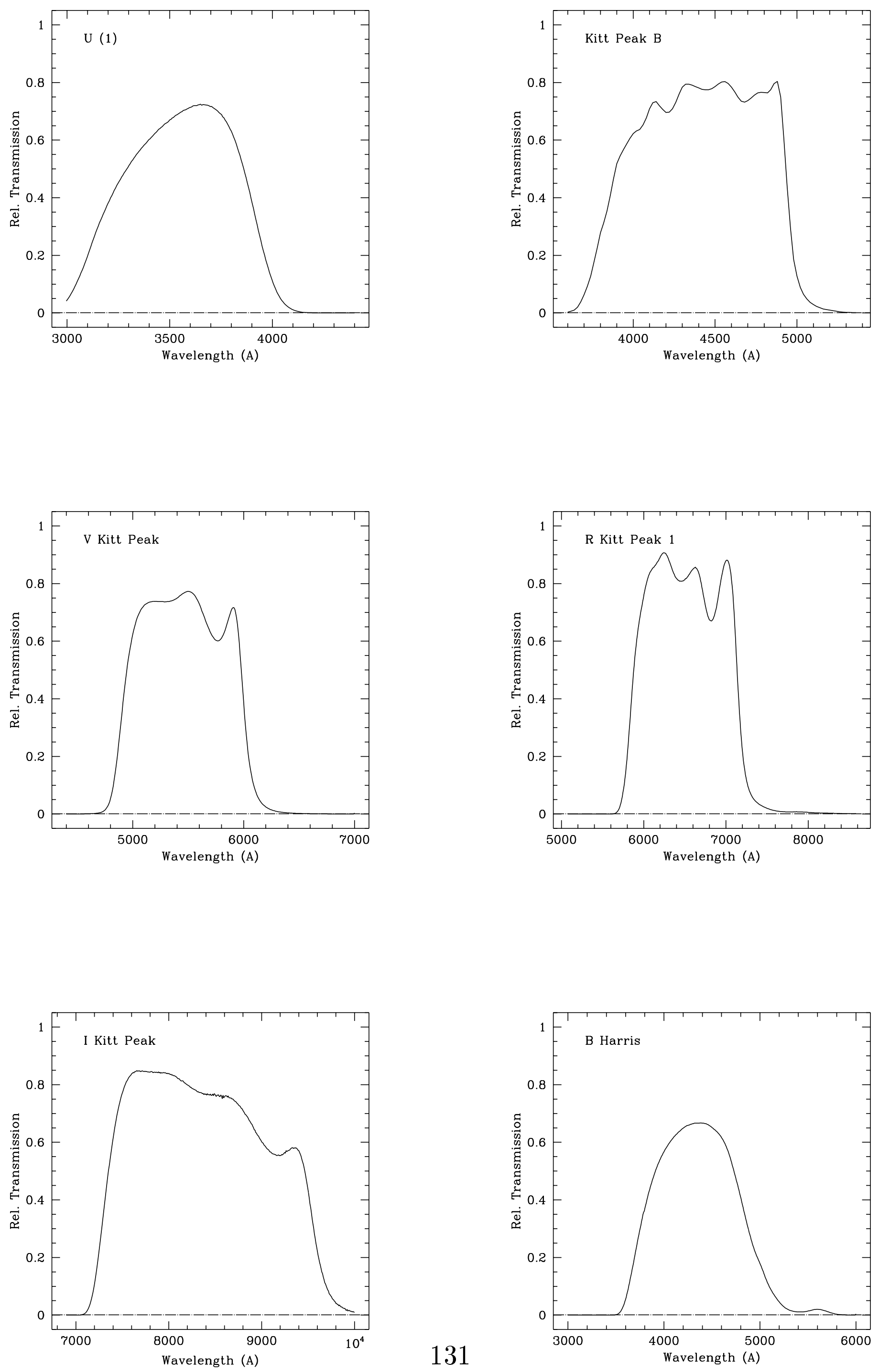


Figure 16: Kitt Peak/Harris filters

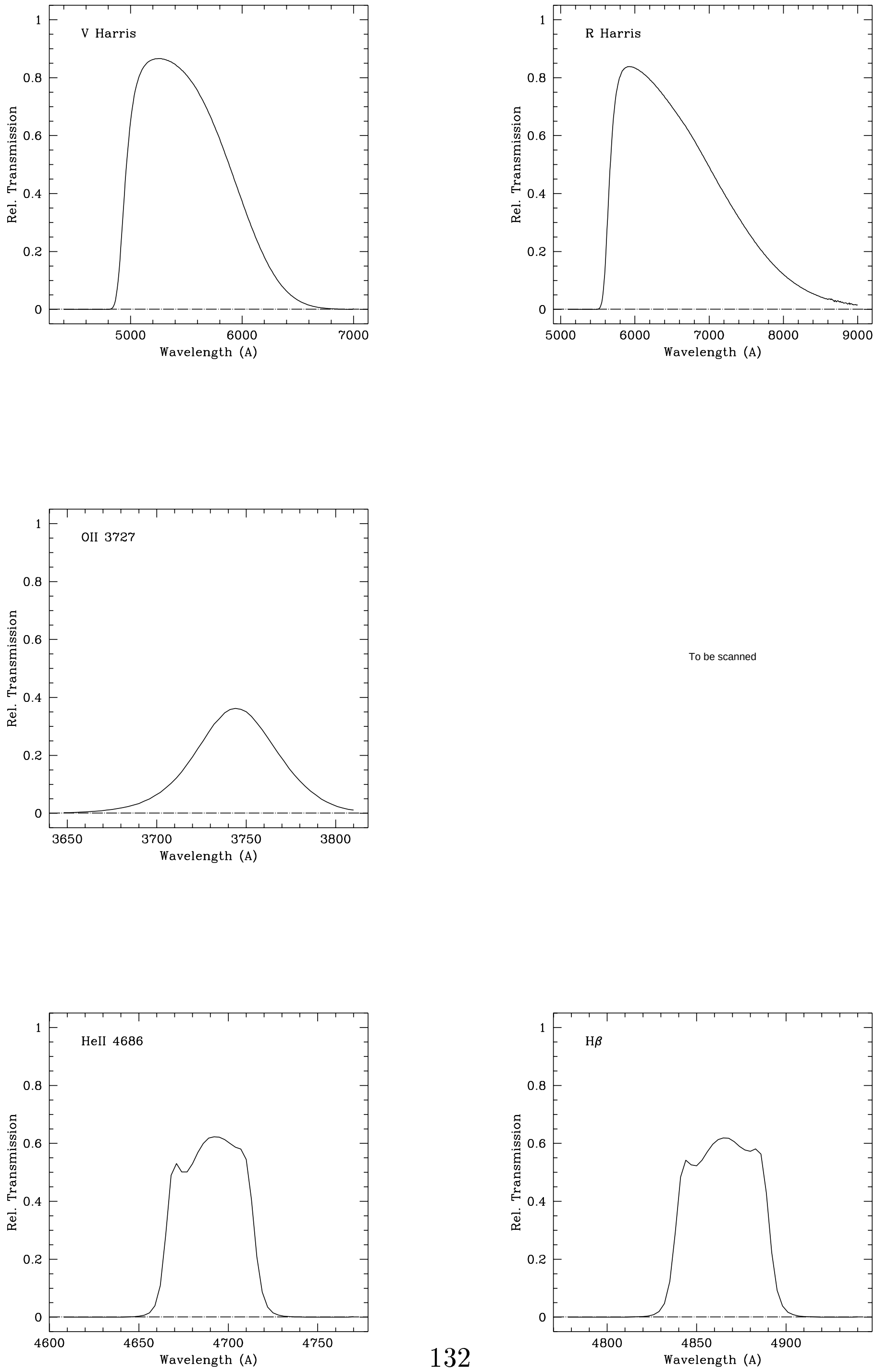


Figure 17: Harris/Narrow Band filters

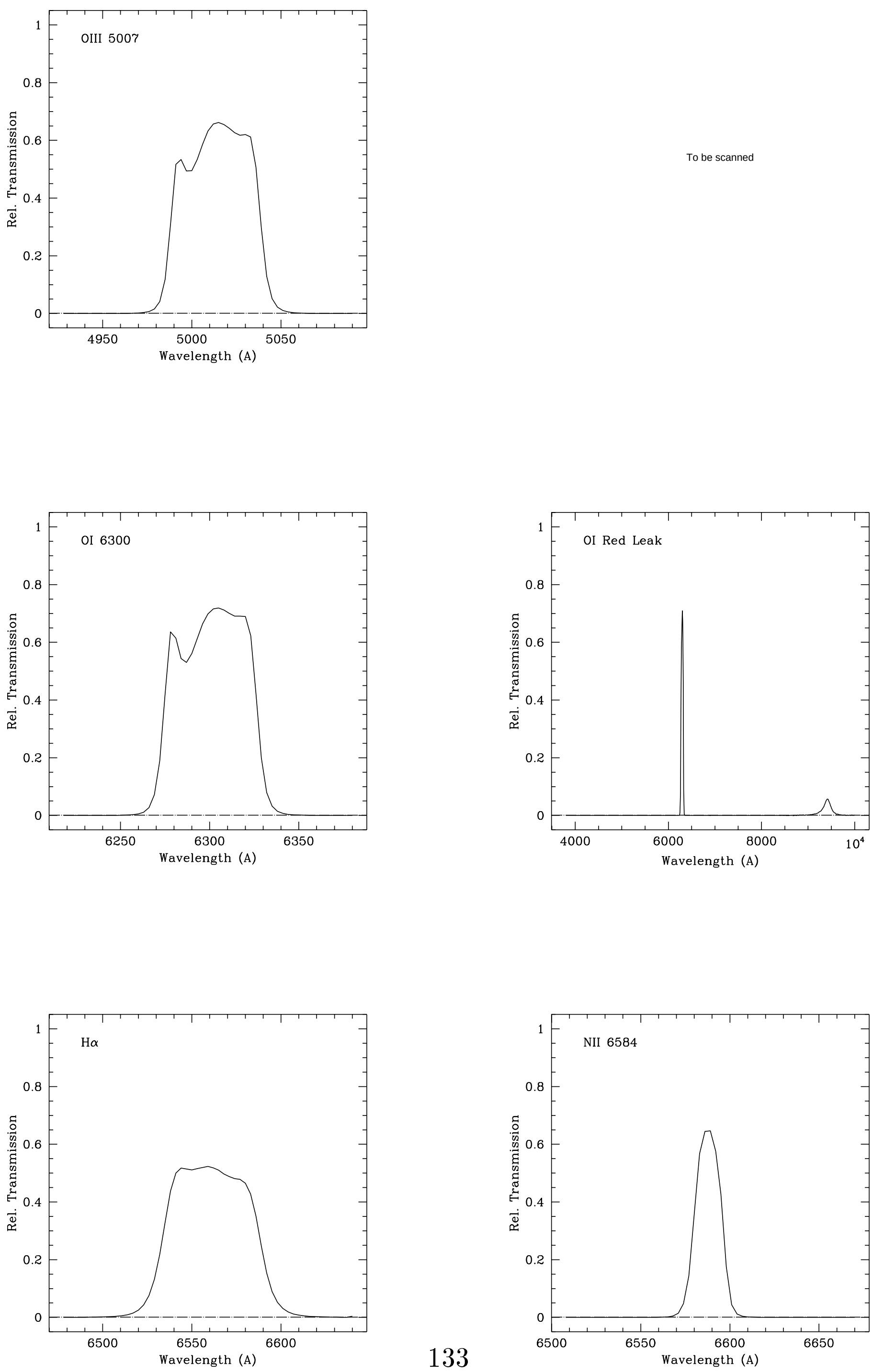
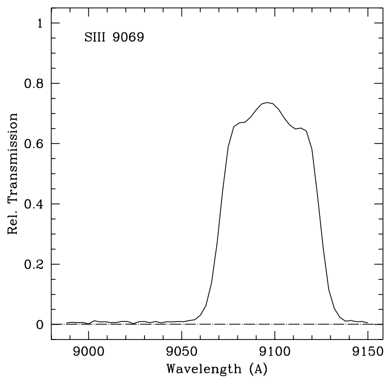
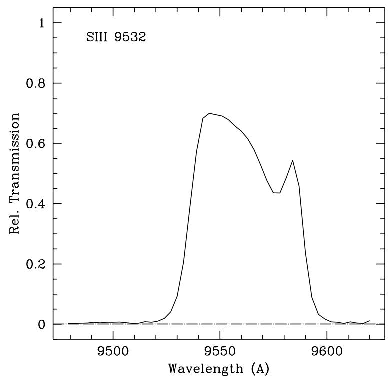


Figure 18: Narrow Band filters

To be scanned

To be scanned





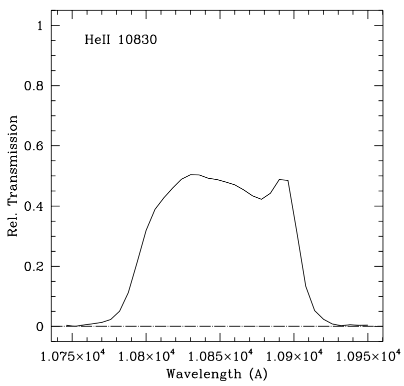


Figure 18: Narrow Band filters

H_alpha 6562

H_alpha 6607

H_alpha 6652

H_alpha 6697

H_alpha 6742

H_alpha 6787

Figure 19: Redshifted Hα Filters

[Redshifted Hα filters]

H_alpha 6832

H_alpha 6877

H_alpha 6922

H_alpha 6967

H_alpha 6565/45

H_alpha 6565/60

Figure 19: Redshifted Hα Filters
[Redshifted Hα filters]

H_alpha 6595 H_alpha 6625

H_alpha 6655 H_alpha 6685

H_alpha 6715

Figure 19: Redshifted Hα Filters

[Redshifted Hα filters]

B.7 The Prime Focus Camera on the WHT

B.7.1 Mounting the CCD filters

The filter cut-out is designed to take 2.0 inch square filters (in a 51 mm square hole); a 47 mm clear aperture is provided.

In addition, filters up to 56 mm diameter can be accommodated, although in this case light can "leak" around four corners unless a mask is fitted.

Any smaller filters should be mounted within a 2.0 inch square frame which is then readily fitted to the wheel.

The maximum thickness of filter allowed is 12 mm; filters of thickness $\leq$ 3 mm will require packing material to stop them moving about within the 3 mm deep cut-out hole.

Each filter is held in position by three adjustable clamps, each of which consists of three parts: a flat-headed screw, which holds a threaded brass post to the filter wheel under pressure from a coil spring, and the main clamp body which screws on to the threaded brass post.

When mounting a filter in the filter wheel, there should be no need to touch the central screw on each clamp. To mount the filter, turn the clamps anticlockwise on the threaded brass posts (which winds the clamps away from the filter wheel) until the clamps will just clear the filter mounted in the recess. The threaded brass posts should not themselves turn. When the filter is in position, wind the clamps clockwise until they just clamp the filter under light pressure from the springs.

Problems may be experienced with extra thick (>10mm thick) filters. In this case, do not slacken the central screw, but consult one of the La Palma-based support astronomers.

Also, the filter wheel for the Prime Focus should be balanced as well as possible. I.e., if a heavier filter is used in one position, it should be matched by a heavy one in the opposite position if possible. This will help to avoid reluctance to move from one filter position to another, or even filter movement during exposures.

B.7.2 Calculating Focus Offsets

Focus offsets for a filter of thickness t can be calculated as follows:
Consider the light from a converging beam falling on a translucent plate of thickness t and refractive index n as shown in Figure 20.

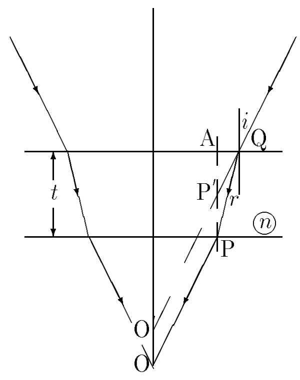


Figure 1:

The angle $\widehat{APQ}$ is the angle of refraction r,

so $sinr = \frac{AQ}{PQ}$

The angle $\widehat{AP'Q}$ is the angle of incidence i.

so $sini = \frac{AQ}{P'Q}$

herefore $n = \frac{AQ}{P'Q} / \frac{PQ}{AQ} = \frac{PQ}{P'Q}$

If i, r are small,

$n = AP/AP'$

Figure 20: The light path of the WHT-PF near the filter

Now the change in focus $OO' = PP' = AP - AP' = AP(1 - \frac{1}{n}) = t(1 - \frac{1}{n})$

For the glass broad-band filters (and also the Kitt Peak filters), the refractive index is 1.6, so the focus offset = 0.38 t. A second correction is needed, due to the corrector lens. In practise you have to multiply the correction calulated above by (f/f')^2, where f is the focal length without corrector lens, and f' the focal length of the whole system, resp. 2.5 and 2.8. The final change in focus is now $t \times (1 - \frac{1}{n}) \times 0.797$.

For the interference filters, the values for the refractive indices are approximately 1.45 for the OII(3727Å), SII(4070Å), HeII, Hβ, OIII, HeI(5876Å), OI and NII filters, and 1.48 for the Hα, SII(6724Å), OII(7325Å), SIII(9069Åand 9532Å) and HeI(10830Å) filters. (N.B. Do not use the refractive index of the substrate, which, although of large refractive index (~2.1), is thin and enclosed in thick glass.

The telescope can be automatically compensated for the filter thickness using the ICL PSETFOC routine (see Section 4.5).

B.7.3 Calculation of Central Wavelength

When interference filters are used at angles other than normal incidence, the optical path difference between the direct transmitted beam and the multiple order reflections within the cavity decreases, causing a corresponding decrease in the wavelength of peak transmission. Changes in the bandwidth and transmission characteristics are generally small (for the relatively wide passbands used here).

For angular tilts of less than 30°, the central wavelength can be calculated from the expression

$$\lambda_\theta = \frac{\lambda_0\sqrt{n^2 - sin^2\theta}}{n}$$

where λ_0 = Central wavelength at normal incidence

λ_θ = Central wavelength at the off-normal angle,

θ

and n = Effective refractive index of the total filter.

B.7.4 Change due to uncollimated light

Utilising the filter in uncollimated (i.e. convergent or divergent) light involves slightly more complex considerations. Here, light enters the filter at a range of angles, so that different rays undergo unequal wavelength shifts. This results in not only a central wavelength shift, but a broadening of the bandwidth and lower peak transmission.

As a rough approximation, relatively uniform beams (with full cone angles less than 20°) will undergo peak shifts of approximately one half of that which would be predicted for a collimated beam at the maximum angle of incidence of the cone.

$$\text{Therefore, } \lambda_\theta - \lambda_0 = \frac{\lambda_0}{2}(\frac{\sqrt{n^2 - sin^2\theta}}{n} - 1)$$

The filters were specified for a focal ratio of 4.5, having a maximum angle of incidence of the cone of 6°.34, and of effective refractive index 1.6.

Substituting these values in the equation,

$$\lambda_\theta - \lambda_0 = -0.0012\lambda_0$$

The focal ratio of the WHT prime focus is 2.8, which gives a maximum angle of incidence of the cone of $10^\circ.2$, so, substituting again into the equation,

$$\lambda_\theta - \lambda_0 = -0.0031\lambda_0$$

Therefore, at the WHT prime focus, the central wavelength (i.e. the wavelength of peak transmission) is shifted towards shorter wavelengths by 0.15% from the specified central wavelengths. For example, for an H_α filter with specified central wavelength 6560Å, the effective central wavelength will be 6550Å.

B.7.5 Change due to temperature

Temperature changes affect a filter's performance due to thermal expansion and contraction of the materials used to construct them. Most filters are designed and specified for operating at 23°C, and deviations from this value in the range of -60°C to +60°C will produce peak wavelength shifts approximately linear with temperature. The exact shift coefficient will depend on the particular design wavelength of the filter, and, typically, ranges between 0.2Å and 0.3Å per °C at 4000Å and 6500Å respectively. Bandwidth and peak transmission changes observed are relatively minor, of the order of 0.01Å per °C and 0.013Å per °C respectively.

The interference filters were specified for working at 10°C, so temperatures significantly different from this will affect the effective central wavelength of the filters.

For example, at an ambient temperature of 0°C, an $H\alpha$ filter with specified central wavelength 6556Åwill have an effective central wavelength of 6553Å.

B.8 Special Purpose Filters

There is an additional set of interference filters which can be used for narrowband imaging at the WHT, or as order-sorting filters for instruments such as TAURUS or UES. See the La Palma Observers' Guide for details of these filters.

C Details of the La Palma Sky

C.1 Sky Brightness and Spectrum

Typical sky brightness at La Palma, in mags per square arcsec, are given below, in 'dark', 'grey' & 'bright' time. *These data refer to clear conditions* (no cloud or dust; low aerosols; extinction at V between 0.10–0.16 mag/airmass).

Table 18: La Palma Sky Brightness (Mag/Square Arcsec)

U	B	V	R	I	Moon	Data Source
21.4	22.3	21.4	20.4	19.3	Dark	JKT+Peoples Photometer, June 1984
21.0	21.8	20.8	20.4	19.4	Dark	JKT + CCD June-September 1989
19.9	20.3	20.1	19.6	19.0	Grey	" "
17.4	17.4	16.9	17.5	17.7	Bright	" "

In the Table, 'Dark' means Moon below the horizon; 'Grey' means above the horizon with phase 0.58-0.67, and 'bright' means above the horizon with phase 0.90-0.96. *The sky data are guidelines*; precise values depend *critically* on angular distance from the Moon, the elevation of the Moon, and the atmospheric aerosol & dust content.

The dark-sky variation between 1984–9 may be partly due to a correlation with phase of the 11-year Solar cycle; a variation of 0.5 mag has been reported by the UK Schmidt Telescope, but because of the lower geomagnetic latitude of La Palma a slightly smaller amplitude is expected here.

Flux–calibrated, low–resolution night sky (airglow) spectra have been presented by C.R. Benn (*Gemini*, **35**, p 20, 1992) and by C. Jenkins & S. Unger (*ING La Palma Technical Note No 82*). Note that in the red, emission lines from OH and H_2O molecules dominate the spectrum, and so the broad–band magnitudes given above do not give a good idea of the sky continuum flux at any particular wavelength.

C.2 Extinction at La Palma

The extinction as a function of wavelength has been tabulated by D.L. King (*ING Tech Note No 31*); a data file and interpolation program are stored in the [LPINFO] directories at Cambridge and La Palma. These data are valid only for a very clear night with low aerosol content, and correspond to an extinction of 0.10 mag/airmass in the 'V' band. (A value of 0.15 is more typical, and values above 0.18 will usually include a contribution from dust). The actual extinction for any (clear) night can be obtained from the Carlsberg Meridian Circle data (also stored in [LPINFO]), and for values at 'V' between 0.08 & 0.16, the extinction curve usually has the same shape as King's curve.

The King extinction curve is repeated here. m is the value in magnitudes per airmass. Note the low value at 5500Å.

Sahara dust can extinguish starlight and reflect light from the Moon and streetlamps. Although it is thought normally to be grey in extinction at optical wavelengths (D. Jones, *Tech Note No 10*; D. Stickland et al., *Observatory*, **107**, 74, 1987), very non-grey extinction has been reported once (Andrews & Williams, *ibid*, **109**, 15, 1989).

Table 19: La Palma Standard Extinction Curve

λ	m	λ	m	λ	m
3000	3.7150	5700	0.1001	8400	0.0143
3100	1.5961	5800	0.0950	8500	0.0136
3200	0.9908	5900	0.0887	8600	0.0130
3300	0.6967	6000	0.0891	8700	0.0124
3400	0.5934	6100	0.0844	8800	0.0118
3500	0.5146	6200	0.0770	8900	0.0113
3600	0.4554	6300	0.0702	9000	0.0108
3700	0.4061	6400	0.0638	9100	0.0103
3800	0.3633	6500	0.0575	9200	0.0099
3900	0.3260	6600	0.0524	9300	0.0095
4000	0.2935	6700	0.0473	9400	0.0091
4100	0.2649	6800	0.0428	9500	0.0087
4200	0.2397	6900	0.0389	9600	0.0083
4300	0.2175	7000	0.0356	9700	0.0080
4400	0.1986	7100	0.0330	9800	0.0077
4500	0.1811	7200	0.0307	9900	0.0074
4600	0.1664	7300	0.0282	10000	0.0071
4700	0.1529	7400	0.0268	10100	0.0068
4800	0.1424	7500	0.0254	10200	0.0065
4900	0.1320	7600	0.0213	10300	0.0063
5000	0.1244	7700	0.0202	10400	0.0060
5100	0.1179	7800	0.0192	10500	0.0058
5200	0.1120	7900	0.0183	10600	0.0056
5300	0.1087	8000	0.0174	10700	0.0054
5400	0.1046	8100	0.0165	10800	0.0052
5500	0.1020	8200	0.0157	10900	0.0050
5600	0.0991	8300	0.0150	11000	0.0048