Roque de los Muchachos Observatory

William Herschel Telescope

UES USERS' MANUAL

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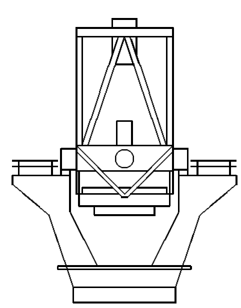

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Chapter 1

Introduction

This introduction is intended for observers new to UES. Observers familiar with UCLES or similar spectrographs under multi-computer control will recognise many aspects of the discussion.

1.1 The Utrecht Echelle Spectrograph UES

UES (fig 3.1) is part of an *observing system* for high-resolution spectroscopy over the wavelength range 3000 to 11000 Å. Highest-level control of this observing system is intended to be from the observer's terminal, by means of simple yet powerful commands in Instrument Control Language (ICL). These initiate sequences of commands at several lower levels, finally moving the optical hardware, controlling exposures and manipulating the data. All the necessary auxiliary systems (such as the telescope and detector) are also under ICL control, so that the user need not know the constituent parts of the system in intimate detail, but can control them globally, in ways that are logical to a *system* user. Although such highest-level control will probably never be perfect, and ad-hoc or makeshift actions at lower levels will often be necessary, the visiting observer should start by considering the system as one organic whole, and only descend to lower levels as necessary.

There are several *aspects* to the UES system, which will be covered separately in this introduction.

1.1.1 Optics

The optical function is the core of the system and the reason for its existence. All supporting systems are derived from the optical requirements. The optical system may be summarised as follows:

One of the Nasmyth foci of the alt-azimuth WHT is dedicated to the cross-dispersed echelle spectrograph UES and its supporting facilities.

The light path comprises:

1. WHT primary, secondary, Nasmyth flat. These are always in the beam.
2. Image (de)rotator, to control by computer the orientation of the slit projected on to the sky. This unit may be mounted or removed during the day. It must be present for extended sources; it must

be absent for polarimetry (planning of this is still in a very early stage); for other applications, the trade-off is between ease of operation and throughput. Acquisition and guiding is not yet implemented without the derotator.
As of Jan 1994 UES is always used WITH the derotator

3. Nasmyth Acquisition and Guiding unit (A&G), always present, comprising the following computer-controlled functions:
   - Acquisition and guiding facilities (manual and/or automatic, object itself or offset)
   - Calibration light injection
   - Filtering (wavelength band, neutral attenuation, polarisation)
4. UES itself, comprising the following computer-controlled functions:
   - Slit unit:
     - adjustable slit width
     - adjustable slit length (Dekker masks on a slide)
     - adjustable slit orientation (limited range; for aligning a selected spectral order with the CCD columns)
   - Shutter
   - Collimator (choice of UV or standard; focus)
   - Hartman shutter for focusing the collimator
   - Cross-dispersion prisms (to separate echelle spectral orders horizontally)
   - Echelle grating for high spectral dispersion vertically (choice of 2 echelles for optimal trade-off between spectral coverage and sky subtraction; 2 angle adjustments for optimisation of the portion of the spectrum recorded by the detector)
5. Camera (folded Schmidt type)
6. Detector (choice of CCD or IPCS-II, but changes must take place during daytime)

In routine use from the observer's terminal, UES is configured for the desired observation, the telescope is pointed to the desired object, the object is centred and (auto)guiding is started. After calibration exposure(s), science exposure(s) and more calibration exposure(s), the observational sequence is complete and the next object is tackled. The digital images will have been saved for later reduction, but can also be inspected by quick-look facilities.

The format of a UES spectrum (and the portion of it recorded by the detector) are shown in fig. 3.6.

Polarisation facilities do not exist as yet but are planned, *for point sources only*. For such observations the derotator will have to be removed from the beam and a polarisation module will have to take its place. A polarisation model of the WHT Nasmyth optical train will have to be developed as part of polarisation commissioning. All of this is technically feasible, but will take time and effort to implement.

1.1.2 Mechanics

WHT is an alt-azimuth telescope with overall pointing accuracy better than 1.5 arcsec (provided the telescope model for the relevant focal position has been updated sufficiently recently). The optics support structure is mechanically decoupled from the coarser mechanical structure ('Nasmyth platform') used for electronic cabinets, handling equipment, and personnel. WHT Nasmyth instruments are mounted on 'instrument support pads', which form part of the optics support structure of the telescope.

UES, its camera and detector, and the dedicated A&G, are all mounted on an optical table, which is kinematically supported on a steel frame, which in its turn is rigidly bolted to the instrument support pads (steel on steel, no thermal effects). The fixed point of the 3-point kinematic support is below the UES slit. The image derotator is also, but separately, connected to the WHT optics support structure. These arrangements ensure that the whole optical system can perform operationally *as a single system,* to the limits of the design of its constituent parts; the observer merely verifies that WHT delivers a good image to the slit and can take for granted that UES turns that image into a spectrum which the detector and subsequent computers record for posterity.

All the electronics, and (for the time being) the temperature control unit, are mounted on the 'Nasmyth platform'; this arrangement isolates the optics from vibrations such as produced by the temperature control unit. The optical table is within a constant-temperature enclosure, to obtain sufficiently stable conditions for proper operation of the spectrograph (cf. the traditional Coudé room for older high-resolution spectrographs). The camera, detector and the A&G unit are outside the constant temperature enclosure, for reasons of accessibility, but are supported by the optical table through the walls of the enclosure. Where necessary, invar has been used in the camera and A&G unit, to preserve mechanical fidelity under slowly-drifting ambient temperature.

The UES thermal enclosure and the calibration light facility of the A&G have slacker tolerances on positional stability and are bolted to the support frame, i.e. are more or less directly supported by the instrument support pads.

1.1.3 Control hierarchy

The aim in the design of the control system has been to allow the observer (eventually) to control the entire observing machine from a single terminal (aided by displays such as TV, autoguider, MIMIC and DMS). To avoid complex interactions of unrelated parts of the system, a hierarchical design was imperative; this is mainly reflected in the software, but also in lower levels of the hardware.

To allow all parts of the system to communicate with each other when necessary, an Ethernet system runs through the entire electro-mechano-optical complex. Source and destination of each message are identified within the messages and each local device uses only the messages meant for it. Wherever there is a concentration of devices to be served (controlled or read out), a Network Interface Unit (NIU) picks up the messages intended for up to 4 local subsystems. The NIU extracts the bare message and passes it to a local microprocessor for further attention. Such a local microprocessor may be the Telescope Control Computer (TCS), a detector controller, a 4MS system controlling an instrument (or an A&G), or a powerful controller for the Autoguider (....) or Data Memory System (DMS). Some of these systems (such as a 4MS) control still lower levels of 'intelligent' microprocessor control (such as Stepping Motor Drive Module SMDM, Barcode Reader Module BCRM or a UES Standard Electronic Control Unit SECU), which control the opto-mechanical assemblies either directly or through still lower levels of control such as dedicated motor control chips. In other cases (such as the Nasmyth A&G and TAURUS), the 4MS system directly controls electronic hardware which in turn contains the basic motor control in hardware form (digital and analogue servos with integrated encoders which are not accessible to the software).

This Ethernet structure emphatically does not include a hardwired hierarchy: any subsystem can in principle control the others. So at the levels of Ethernet and above, the software must define the hierarchy. Below the NIU's, the hierarchy is mostly hardwired.

Since the hardware is from different sources (DEC, RGO, Dwingeloo, Utrecht and Roden, to name a few prominent in UES), unity of results must be imposed at some level. Ethernet messages must conform to a certain protocol, and the several 4MS systems also work mainly with standard hardware selected by RGO and use RGO's standard basic kernel. Below the 4MS systems, individual preferences and equipment demands run riot, above the NIU's the reign of Ethernet and the VAXes is supreme.

However the hardware is implemented, the principle of hierarchical control is always to start an action, then forget about it at the initiating level until the next level down signals its completion. At that point, a status variable is updated in the initiating system, so that the level above can, by a simple 'read status' message, find out what state the system is in; while a device or system is in transit from one well-defined state to another, its status is 'undefined'. The MIMIC display shows the observer what the recorded state is of each component of interest to him (green for a well-defined state, white for undefined, red for error). At the very highest control level (ICL), the aim is that the observer can use a single command for the equivalent of such sequences as: *Configure UES according to table x, the CCD window and binning according to table y, point the telescope to NGCnnnn (from catalogue abc), set the UES slit position angle to θ on the sky, centre the object for maximum detector output, find the nearest star brighter than magnitude m and lock on to it for autoguiding. When all of this is properly set up, start a 20-minute exposure and, 5 minutes before its end, sound the buzzer in the coffee room. Oh yes, calibration spectra both before and after NGCnnnn, please; use the lamp which is most suitable for my spectral region. Data to be displayed on the DMS for as long as this does not interfere with the next exposure, and also saved on disc. Quick-look reduction; observer control of the observing sequence to do repeats on failed or especially interesting exposures.*

If this were all that observers needed, monolithic control from a single computer would in theory be possible (though distinctly unfriendly to service-technicians). However, other observers want sequences of exposures for polarimetry or time-variability, or an automatic telescope focus test, or the same signal-to-noise for objects of different brightness, etc etc. The control hierarchy has been designed to cater for all of these situations and many more that are still dormant in future observers' minds. The system of status variables, available on demand to the next level up, allows construction of simple commands performing complex sequences of actions at the next lower level, of the type: 'Start this, wait for it and, if successful, start that and wait again'. This works fine (though slowly), until an error condition develops; in that case, the error information must propagate all the way to the observer (unless an intermediate level of control has been programmed to correct the error and put the system back on to the rails).

Observers will appreciate that, even when the hardware is installed and has proved reliable, the complex sequences at the behest of ever changing observers require a substantial amount of programming at a number of levels in the hierarchy; this is the price one pays for present and future flexibility. Since, for historical reasons, the languages (or dialects) in the computers are mostly different, arranging for a new top-level application to be automated requires many months of hard labour. Therefore, observers who wish to do state-of-the-art observational work have no option but to assist in a continuing task force which repeatedly reprogrammes parts of the system; they must be prepared to help out wherever a vacancy threatens and they must be prepared to use temporary fixes at some lower level of control than the observers' terminal. More pedestrian observers, who are happy to do large projects after the bugs have been taken out, can skip the rest of this section on control. It is for the would-be state-of-the-art observers that the control hardware and software is summarised below.

1.1.3.1 Hardware

Bearing these generalities in mind, it is now profitable to examine figs ?? to ??, which represent the hardware of the control hierarchy of the UES-related installation.

The observers' terminal and MIMIC display are peripherals of a VAXstation, which communicates over Ethernet and NIU's with the TCS telescope control computer, with the UES/A&G 4MS, with the Autoguider processor (and its CCD controller), with the science-detector controller, and with the DMS and its link to the data reduction computer. Separate direct fast data links exist from detector controllers to the computers receiving the data (Autoguider and DMS). There is also a separate TV facility from the A&G (camera) to the observer in the control room (display), and a DECnet connection between the observers' VAXstation, the reduction VAX and the DMS processor. To add to the confusion, the VAXstation runs WINDOWS, allowing the observer to run several concurrent tasks in different computers from one terminal.

At the next level down, the following computers control more mundane details:

- The TCS controls telescope motors, hydraulic bearings, etc from information it revceives from encoders, pressure gauges and such, through a CAMAC installation (interface electronics which is largely computer-independent). Error signals derived by the autoguider computer from centroiding on the image of the star selected for autoguiding feed into the TCS to preserve tracking fidelity under changing (atmospheric and other) conditions. The TCS also controls the image derotator and the dome.
- The UES and its A&G are controlled by a single 4MS system (figs ?? and ??), respectively through local SECU processors and hardwired electronics (both of which allow the 4MS to start an action and forget it until it is complete)
- CCD controllers for the science and autoguider CCD's set up and generate the timing sequences of the voltages required by those detectors.
- The Autoguider computer accepts the CCD image on the data input, analyses it for star position and derives the error signals, which are combined with known probe position (available from the A&G 4MS) and fed to the TCS to correct telescope tracking to obtain a stationary star image on the CCD.
- The DMS processor examines the data in the Data Memory according to the observer's commands (histogram, x-cut, y-cut, centroid, etc) and controls the extent and order of transfer of the data to the reduction computer.

Each of these lower-level processors has its own repertoire of instructions; 2 sources generate most of these instructions:

1. The Ethernet input
2. The processor's operator terminal (not to be confused with the observer's terminal, which is a peripheral of the VAXstation); such operator terminals are generally stationed in the control room, but can be used at the location of the processor for tests.

Generally 1) is used during hierarchical control and responses are returned over Ethernet, while 2) is used for engineering tests. However, 2) has a command to simulate Ethernet messages and an experienced operator (support astronomer in some cases) can use the local terminal to save the day when connections fail *(even in normal operation, telescope and autoguider control, and DMS operations are often done this way by preference; this is extremely confusing to the novice observer, but in practice it can be the most efficient way of coaxing results from the installation, given the presence of a highly-skilled support astronomer and/or telescope operator; it should never be the end-point of development, as it is far too failure-prone for comfort and is expensive in that it involves highly-skilled support staff rather than the observer himself).*

At lower level still, BCRM, SMDM or SECU processors again have their repertoires of instructions and responses, but communicate over RS232 or similar lines with the controlling 4MS. They do not usually have an operator's terminal, but the controlling 4MS can be set to be transparent, so that the 4MS operator's terminal can perform this task.

Documentation exists for most of the processors mentioned. The observer should not need any of these, except when he gets involved in setting up new observing modes.

The more reliable the lower levels are, the higher the level of integration at which the installation can operate successfully. Hence commissioning always starts with simple functions at the very lowest level and includes the fidelity of error-reporting to the next level up. After careful verification at several levels, the observer can reliably control all elements of the system using ICL from his one terminal (that is, without using WINDOWS for transparent connections to other computers in the system, which would be cheating). Only then is it possible to set up sequences of commands in Control Files, to be processed by the observing system in 'batch' mode, with the observer merely monitoring it all. Once this stage is reached, true remote observing can be contemplated for the more routine observing programmes; as indicated, we have not yet arrived at this point by a long way (and such observing will always depend heavily on preventive maintenance by site staff).

1.1.3.2 Software

The top levels of the software run on the observer VAXstation, as tasks started up under the ADAM real time monitor (which is programmed in FORTRAN, has FORTH-like structures incorporated and runs under VMS/Windows).

The high level ICL commands (or sequences of ICL commands executed as ICL command files) are passed to the ADAM Cd and D tasks (one Cd task for the complete facility, plus one D task for each local processor involved). These ADAM tasks, after checking the formal existence of the command, its syntax and the parameter range, translate it into the string required by the destination microprocessor. The D task adds Ethernet code for source and destination, and passes it to the NIU for transmission. After Ethernet transmission, the destination NIU extracts the bare message and passes it to the required local controller (4MS or such). After more syntax and parameter checking, the local controller activates the mechanism hardware in one way or another, and monitors for completion. During all this time, the VAXstation, through its MIMIC task, shows the component status as 'undefined' (i.e. in white, at the old or an intermediate position) on the MIMIC screen (any explicit 'immediate status request' at this stage will also return 'undefined' status and have the same effect on the MIMIC screen).

The usual practice is for the D task to issue a 'delayed status request' for the component with every 'move' or 'initialise' command. This causes the local controller to return an Ethernet status message, but not until *after the component has arrived at its target.* The NIU and D task pick up this status return, the Cd task updates the component status in its table and the MIMIC task detects this status change, causing it to show the component in green on the MIMIC screen, at its new position.

All of this is in asynchronous operation, the process will take as long as is necessary for the mechanism concerned (plus an overhead of seconds for all the message-passing). All mechanisms or functions in all local controllers are accessible simultaneously, subject to traffic density on Ethernet. Any errors detected (such as timeout or communication error or parameter out of range) are reported all the way up, ending with the component shown in red on the MIMIC screen; an 'immediate status request' at that point will usually inform the observer about the nature of the error (though not always about its cause).

Where speed is critical, there are special solutions, in hardware or in software. However, the above is the basic principle and it works, for those who are prepared to wait. The price of flexibility is sluggishness, but much of the 'lost' time is recovered by the observer-proofness of the whole arrangement.

Most of the local controllers work in one FORTH dialect or another; this makes them powerful and fast, but the programmes are difficult to read and service. One hopes never to have to reprogramme 4MS, SMDM, Autoguider VME, CCD controller and such; this would require inhuman foresight on the part of their designers and in fact modifications are needed every few years as new applications emerge from development. For ease of adaptations, the software in most of these systems is based on a table of permitted functions and parameters, and a status array which faithfully reflects the real-life equipment. An excellent description of this RGO FORTH kernel is to be found in the ISIS 4MS manual ER 422.

1.1.4 State of the Union

The operational union of WHT, UES, A&G, detectors and software is, at the time of writing, good—users express themselves happy with the facility and demand for bright time has now increased to the same level of oversubscription as demand for dark time. One exception in this happy state of affairs is the field size of the autoguider and slitviewer options; an enhancement is now being implemented, which will produce a more practical field of view, at the expense of (ultra-)violet capability of this subsystem.

The operational stability of UES itself over 12 hours of normal observing has been found to be of order 0.01 Å or 0.6 km/sec. This result is the best tribute imaginable to the basic soundness of the system design, which in turn dictated the mechanical structure. Use of the calibration light system allows effective stability over an entire observing run to be determined by the residual drifts over say 30 minutes or less; to make full use of the calibration facilities for the most stringent applications, lamps can be allowed to stabilise before a calibration exposure is started (observer-controlled shutter associated with each lamp).

Basic ICL control and MIMIC feedback seem to be reliable, but observer control by ICL procedures is in its infancy. During the next few years, a substantial improvement in this area may be expected, with resultant huge increases in observer efficiency for routine applications.

1.2 Scope of this manual

This manual describes the design, operation and performance of the Utrecht Echelle Spectrograph (UES).

The manual starts with a quick reference section, Part 2, which contains summaries of command lists and useful numbers. This section is for people who are familiar with the instrument, but need to refresh their memories.

The manual then goes on to describe the UES observing system in more detail. This observing system can (somewhat arbitrarily) be divided into the following sub-systems:

- The telescope
- The derotation optics
- The A&G unit
- The spectrograph
- The detectors
- Data acquisition
- Data reduction

Parts ??, 4 and 5 of this manual describe the design and general principles of operation of the three sub-systems listed above which are specific to UES: the spectrograph itself, the derotation optics and the A&G unit. The telescope and detector sub-systems are in common to all WHT instruments, and have their own user manuals.

Part 6 describes the overall performance of the spectrograph.

Part 7 describes in more detail how the observing system is set up and used for routine observing. Part 8 describes diagnostic and setup procedures.

Part 9 is a reference section specifying in detail the ICL commands used to operate the UES and its A&G. The commands for the other useful subsystems (telescope and detectors) are not listed here, further details can be found in the following manuals (copies of which can be obtained from Bill Martin at RGO–Cambridge): elsewhere:

- The La Palma—Isaac Newton Group—Observers Guide (1994)
- The WHT Users Manual (1994)
- The WHT Autoguider User Manual (1993)
- The WHT Data Acquistion System Manual (1993)
- The IPCS-II User Manual

Part 10 briefly describes the UES planning software whilst Part 11 describes the software available for reducing UES data.

Part 11 gives a brief summary of the STARLINK supported ECHOMOP package for the reduction of UES echelle data.

1.3 Obtaining copies of this manual

This manual has been prepared using LaTeX. A copy of the current source is held on the La Palma VAX cluster (SPAN node LPVS5 29146 or internet address lpve.ing.iac.es) in directory `[MANUALS.WHT_UES]`, along with its associated rasterized file, `UES_USER.DVI-CAN`. New copies of the manual may be printed out using:

- `WHT_GLASE DISK$USER1:[MANUALS.WHT_UES]UES_USER.DVI-CAN` or
- `INT_GLASE DISK$USER1:[MANUALS.WHT_UES]UES_USER.DVI-CAN`,

(to give output on the laser-printers in the WHT and INT buildings, respectively). A copy is also held on the STARLINK VAXcluster at RGO Cambridge, in the directory `CAVAD::DISK$USER1:[MANUALS.WHT_UES]`.

After 01–April–1994, the CAVAD cluster will be closed and the manual will be transferred to `GXVG::DISK$USER1:[MANUALS.WHT_UES]`

Additionally the manual is held on-line, accessible to GOPHER users — gopher to ing.iac.es and the manual is held in Telescopes/WHT/UES

1.4 Other documentation

The present manual is designed to be the main reference for the operation of UES and its A&G unit. Observers will also need to refer to the WHT Users manual for information on the operation of the telescope, and the WHT data acquisition system manual for information on operation of the detectors. Further background information may be found in the *Observers' Guide* (1994 edition).

1.5 Getting help

In case of difficulty, consult your Support Astronomer or Duty Technician. More specialist advice may be obtained from Nic Walton (naw@lpve.ing.iac.es) or Max Pettini (pettini@mail.ast.cam.ac.uk).

1.6 Notation

The following conventions for computerese have been used more-or-less consistently throughout this manual:

- Examples of commands entered at the terminal are in typewriter font: `USLITWIDTH 50`, as are messages from the computer;
- Angle brackets denote parameter values or character strings: <`angle`>;
- Square brackets denote optional input *e.g.* `[x,y]`; all other parameters are obligatory;

Chapter 2

Quick reference section

2.1 Useful numbers

Table 2.1: UES plate scales (see sec 3.2.1)

	Without derotator	With derotator
Scale at slit (arcsec/mm)	4.51	4.44
Scale at detector (arcsec/mm):		
Spatial direction	15.20	14.96
Spectral direction	23.63	23.26

Table 2.2: UES resolving power and velocity resolution (see sec 3.2.3)

Detector	Spatial resolution (μm)	Resolving power	Velocity resolution (km s^{-1})	Wavelength resolution (Å)		
				3000 Å	6000 Å	10000 Å
EEV CCD	45	52,000	5.77	0.058	0.115	0.192
Tek CCD	48	49,000	6.12	0.061	0.122	0.204
IPCS-II	30	78,000	3.85	0.038	0.077	0.128

Table 2.3: Interorder spacing with UES echelles (see sec 3.3.1)

Wavelength (Å)	Interorder spacing (arcsec) (arcsec)	
	31.6 echelle	79.0 echelle
3000	17	43
3500	14	34
4000	12	29
5000	9.3	23
6000	8.1	20
7000	7.5	19
8000	7.5	19
9000	7.8	20
10000	8.6	22
11000	9.6	24

Table 2.4: UES matched slit (see sec 3.3.3)

Detector	Spatial resolution	Matched slit	
	μm	μm	arcsec
EEV CCD	45	236	1.05
Tek CCD	48	252	1.12
IPCS-II	30	157	0.70

Table 2.5: Autoguider mirror options (see sec 5.1.2)

Autoguider mirror position	Unvignetted field diameter at slit (arcsec)	Partially vignetted field diameter at slit (arcsec)	Field at reflected focal plane (arcsec^2)
GUIDEONLY	0	0	
POINTSOURCE	18	170	
SHORTSLIT	73	213	
LONGSLIT	161	271	
CLEAR	161	271	

Table 2.6: Telescope and autoguider focus (see 7.3.1

Date	Telescope focus	Autoguider focus
)		
11/2/92	101.65	180
21/12/93	??	??

2.2 Filter wheel contents

Table 2.7: Main beam colour filters (see sec 5.1.3)

Usual position	Name	Thickness (mm)
1	Empty	
2	UG11	3.5
3	UG1	3.5
4	BG28	2.5
5	BG38	2.5
6	GG385	3.5
7	GG420	3.5
8	GG495	3.5
9	OG590	3.5
10	RG715	3.5
11	RG830	3.5

Table 2.8: Main beam ND filters (see sec 5.1.3)

Usual position	Name	Thickness (mm)
1	Empty	
2	ND0.4	2.2
3	ND0.8	2.2
4	ND1.2	2.2
5	ND1.6	2.2
6	Empty	
7	ND2.0	2.2
8	ND2.5	2.2
9	ND3.0	2.2
10	ND3.5	2.2
11	ND4.0	2.2

Table 2.9: Autoguider filters (see sec 5.1.4)

Usual position	Name	Bandpass (nm)
1	RG9	1000 – CCD cutoff
2	ND0.5	
3	ND2.0	
4	RG610	610 – CCD cutoff
5	GG455	455 – CCD cutoff
6	ND3.0	
7	Clear	Everything
8	VG9	470 – 580
9	ND5.0	
10	BG28	350 – 515
11	UG11	300 – 380
12	BK7	380 – CCD cutoff

Table 2.10: Comparison unit colour filters (see sec 5.1.7)

Usual position	Name
1	FG15
2	FG13
3	RG6
4	UG3+GG475
5	RG780
6	KG5
7	LB120
8	FG3
9	512

Table 2.11: Comparison unit ND filters (see sec 5.1.7)

Usual position	Name
1	ND0.5
2	ND1.0
3	ND1.5
4	ND2.0
5	ND2.5
6	ND3.0
7	ND3.5
8	ND4.0

2.3 Command list

Table 2.12: The ICL commands normally used for operating the UES and A&G are listed (see also sec ??)

Command	Parameters	Meaning
UMIRROR	CLEAR/GUIDEONLY/POINTSOURCE/ LONGSLIT/SHORTSLIT/ULAMPS	Move autoguider mirror
UAGX	0–73600	Set X coordinate of autoguider probe
UAGY	0–73200	Set Y coordinate of autoguider probe
UAGXY	0–73600 0–73200	Set X,Y coordinates of autoguider probe
UAGFOC	0–200	Set focus of autoguider probe
UAUTOFILT	1–12 or name	Select autoguider filter
UTVVIEW		View field using TV
UENDTVVIEW		Resets slit angle and dekker after using TV
UPROBEVIEW		View field centre using coarse probe
ULAMPS	name or off	Turn comparison lamps on or off
ULAMPSHUT	name or close	Opens or closes lamphouse shutters
UCOMPFILTND	1–12 or name	Select comparison lamp ND filter
UCOMPFILTC	1–12 or name	Select comparison lamp colour filter
UFILTPOL	1–11 or name	Select main beam polariser
UFILTND	1–11 or name	Select main beam ND filter
UFILTC	1–11 or name	Select main beam colour filter
USLITANGLE	–12000–11400	Set slit angle (mdegs)
USLITWIDTH	value ARCSEC/MICRON/PIX	Set slit width
USLITSHUT	OPEN/CLOSE	Open or close slit shutter
USLITLEN	value ARCSEC/MM/PIX	Set slit length
UCOLL	UV/WIDE	Select collimator
UFOCUS	0–20000	Set collimator focus
UHART	IN/OUT	Moves Hartmann unit in/out of beam
UHARTPOS	UP/DOWN/LEFT/RIGHT	Position of Hartmann shutter
UCENWAVE31	wavelength order	Configures 31.6 echelle for wavelength
UCENWAVE79	wavelength order	Configures 79.0 echelle for wavelength
USLITOFF	value	Sets model offset to slit angle
UTHETAOFF	value MDEG/PIX	Sets model offset to theta
UGAMMAOFF	value MDEG/PIX	Sets model offset to gamma
UCAMSHUT	OPEN/CLOSE	Open or close camera shutter
UPIXEL	value1, value2	Sets detector pixel size in x and y (microns)
UTEMP		Reads UES temperature sensors
UES_INIT	mechanism	Initialises mechanism
UES_UPDATE	mechanism	Reads status of mechanism
UES_CANCEL	mechanism	Cancels ADAM action on mechanism

Table 2.13: The following are ICL commands used for engineering purposes only (see also sec ??)

Command	Parameters	Meaning
UAUTONAME		Set names of autoguider filters
ULAMPNAME		Set names of lamps
UCNNAME		Set names of comparison ND filters
UCCNAME		Set names of comparison colour filters
UFPNAME		Set names of main beam polarisers
UFNNAME		Set names of main beam ND filters
UFCNAME		Set names of main beam colour filters
UNAMES		Set all component names
UEXPOSE	1500–640000	Open slit shutter for specified time
UDEKKER	0–123530	Set position of dekker
UMODLENS	1–7 or name	Moves focal modifier lens wheel
UFMNAME		Sets names of focal modifiers
UPRISMPOS	0–2400	Set prism position
UECHELLE	E31/E79	Select echelle
UTHETA31	−2500–2500	Set theta for 31.6 echelle
UTHETA79	−2500–2500	Set theta for 79.0 echelle
UGAMMA31	–2290–2290	Set gamma for 31.6 echelle
UGAMMA79	–2290–2290	Set gamma for 79.0 echelle
UCAMLAMP	OFF/ON1/ON2	Turns camera LEDs on or off
UPINMASK	IN/OUT	Moves pinhole mask shutter

Chapter 3

The Utrecht Echelle Spectrograph

3.1 Design

3.1.1 Overview

The design of the Utrecht Echelle Spectrograph is identical to that of the spectrograph built at University College London for the f/36 coudé focus of the Anglo-Australian Telescope, apart from unavoidable differences arising from the different focal ratios at the two telescopes. This section summarises the basic design parameters of the spectrograph. A discussion of the design philosophy is given by Walker & Diego *(Monthly Notices of the Royal Astronomical Society, vol 217, p355, 1985)*.

The layout of the spectrograph is shown in Fig. 3.1. The slit S is at the focal plane of the telescope. The light from the slit image (beam a) is collimated (beam b) by an off-axis parabolic mirror C, and traverses the three cross-dispersing quartz prisms P1, P2 and P3 before beam c is incident on the echelle E. L1, L2 and L3 are focal modifying lenses for varying the degree of overfilling of the grating. The axes of beams a, b and c are horizontal. The light is dispersed in the vertical plane (beam d) by the echelle (beam d) and is finally re-imaged by the camera.

The components of the spectrograph are assembled on an optical bench, which in turn is supported by the instrument mounting pads on the camera, is contained within a thermal enclosure in order to maintain it at a constant temperature.

3.1.2 Slit unit and dekker slide

The UES slit has a maximum length of 67.3 mm (5 arcmin), corresponding to the full field transmitted by the Nasymth image derotation optics. The slitlength actually used is defined by the dekker slide or by the autoguider mirror (see section 5.1.2).

The slit width can be continuously varied between .02 and 20 mm (0.09 to 90 arcsec).

The entire slit assembly can be rotated by $\sim \pm 12$ degrees. Note that the reason for rotating the slit assembly is *not* to change the PA of the slit on the sky; this is the function of the image derotation optics (see Part 4). The reason for rotating the slit assembly is that for a fixed slitangle, the slit as projected on the detector will appear to rotate as a function of observing wavelength. It is therefore necessary physically to rotate the slit assembly in order to keep the projected slit aligned with the rows/columns

Figure 3.1: Schematic of the Utrecht Echelle Spectrograph (UES).

of the detector.

A shutter is mounted at the rear of the slit. This is a fast shutter, used for timing CCD exposures. The shutter used is a Prontor magnetic shutter E/100, with a specified maximum opening/closing time of 34 msecs.

At the front of the slit assembly is a dekker slide, which contains a mask used to define the slit length. The dekker mask, usually referred to as the 'Concorde dekker' is illustrated in Fig. 3.2. The shape of this mask allows the slitlength to be set to a high degree of accuracy over the range from 0.33 mm (1.5 arcsec) to 4.62 mm (20 arcsec), and a rather coarser setting of slitlength over the range from 4.62 mm (20 arcsec) to 67 mm (5 arcmin).

3.1.3 Focal modifying lenses

The focal modifier lenses were originally intended to be used to optimize the overfilling of the echelle for different modes of operation, as discussed in detail by Diego & Walker *(Montly Notices of the Royal Astronomical Society, vol 217, p347, 1985)*. In fact, *the poor performance of the lenses (see Appendix C) means that there are no circumstances under which they would be of use, and they have been removed from the instrument.*

3.1.4 Collimators

There is a choice of two collimators, one coated for the short wavelength region ($\lambda < 4000$Å) and one for longer wavelengths ($\lambda > 4000$Å). They are off-axis paraboloids, with a measured focal length for both collimators of 2359$\pm$0.5 mm and an off-axis distance of 295$\pm$0.5 mm, implying an off-axis angle of 7.18 degrees. Space constraints mean that the instrument has in fact been constructed assuming an off-axis angle of 7.39 degrees. The diameter of the collimated beam is 215 mm in the absence of focal modifiers.

3.1.5 Hartmann unit

The Hartmann unit can be inserted into the spectrograph beam just in front of the collimator, in order to focus the spectrograph. The unit contains a mask which obscures half of the collimated beam; by rotating the mask it is possible to select which half of the beam is obscured (top, bottom, left or right). The spectrograph can then be focussed using a Hartmann test as described in sec 8.4.

3.1.6 Cross-dispersing prisms

Prisms were chosen as the cross-dispersing elements of the spectrograph for a number of reasons, one of which is that the inter-order separation is much less dependent on wavelength than in the case of a diffraction grating. The prisms are made of extremely homogeneous fused silica (Corning 7940 fused slica class 2 grade A), which transmits down to 3000Å. This material is specified as having a refractive index homogeneity of 1×10^{-6}.

The prism size demanded by the optical design is beyond the limits of current manufacturing technology. Therefore in order to provide sufficient cross-dispersion, three smaller prisms are used in series, each of which is composed of three smaller parts optically contacted together by means of a UV transmitting fluid (Cargille matching fluid 06350).

The layout and nominal dimensions of the prism assembly are summarised in Fig. 3.3.

Figure 3.2: The UES dekker mask

Figure 3.3: The UES prism assembly

3.1.7 Echelle grating

A choice of two echelle gratings is provided, both supplied by Milton Roy (formerly a division of Bausch & Lomb). The gratings are the largest available, with a nominal ruled area of 204×408 mm.

The two gratings have different rulings (31.6 and 79.0 lines/mm) but have the almost identical blaze angles (nominally 63.43 degrees). *This means that at a given wavelength the two gratings give nearly the same spectral resolution.* This point is worth emphasising, since it is very different from the situation with a conventional intermediate dispersion spectrograph (e.g. ISIS or IDS) using first order gratings. The choice of grating for UES is determined not by the resolution required, but by the slitlength and wavelength coverage required (see Section 3.3.1 for more detail).

3.1.8 Camera

This is of folded Schmidt design with a field flattener lens (Wynne, 1977. MNRAS, 180, 485). The camera design is illustrated in Fig. 3.4.

The nominal focal length of the camera is 700 mm. The nominal field of view is 38.5×18.8 mm; the effect of vignetting at larger field diameters is illustrated in Fig. 3.5. It is important to note that the unvignetted field of view is smaller than many of the detectors used with the instrument; thus part of the detector area will be vignetted.

Two LED's are mounted within the camera, facing the detector. These were originally intended as a source of undispersed light, for use in flatfielding the detector. A red LED is provided for use with CCD detectors, and a green LED for use with the IPCS-II. To date these LEDs are not routinely used, except for occasional engineering purposes.

Between the camera and detector are two shutters. One of the shutters is a safety shutter, which opens slowly but can close very quickly. This is used to protect the IPCS detector; if the IPCS is overilluminated, or the panic button is pressed, then the shutter will close. The other shutter mechanism was orignally intended to carry a 'pinhole mask'; this is a mask consisting of a pattern of holes on a regular grid. The idea was that using this mask in conjunction with the flatfielding LED would make it possible to project a set of reseau marks onto the IPCS detector, in order to map the geometric distortion. The mask has not been useful in practice, and the mechanism has been removed. (?)

3.1.9 Optical table

The UES is assembled on an optical table, supplied by Photon Control Ltd. The table rests on a support frame, which in turn locates on the four instrument mounting pads on the Nasymth platform; the weight of the instrument (approx 5 tonnes) is thus carried by the instrument mounting pads, which are mechanically part of the telescope structure, and not by the nasmyth platform.

3.1.10 Thermal enclosure

The UES must be maintained at a stable temperature to avoid degrading the instrumental resolution. In particular, temperature differences of a few tenths of a degree within the prisms will cause an unacceptable variation in the spectral index. The prisms have a long thermal time constant, of order 24 hours, and so cannot be subjected to sudden changes in temperature.

The main body of the spectrograph (but *not* the spectrograph camera nor the A&G unit) is therefore

Figure 3.4: The UES camera

Figure 3.5: Vignetting in the UES camera

contained within a thermal enclosure, consisting of a number of aluminium panels mounted on a metal frame. Each panel is maintained at a constant temperature by circulating a temperature-controlled fluid (a water–glycol mix) through pipes attached to the inside of the panel. The temperature of the fluid is stabilised by the Tamson unit, which first cools the fluid to below the desired temperature and then heats it by a precisely controlled amount; the reason for this approach is that it is much easier to heat a fluid by a precise amount than to cool it by a precise amount. The rate of flow within each panel can be independently adjusted by means of flowmeters, in order to equalise the flow through different panels.

In order to minimise the amount of heat dumped by the Tamson unit into the dome, the UES should not be kept at the same temperature throughout the year. Instead, the temperature should be changed slowly (i.e. on timescales much longer than the thermal time constant of the prisms), to follow seasonal variations in the dome temperature. Typically the enclosure temperature is adjusted to approximately equal the dome temperature averaged over a 24 hour period, hence 10^0C in the winter months, rising to 15^0C during the summer.

In order to keep the spectrograph optics dry and dust–free, the inside of the thermal enclosure and the spectrograph camera are both flushed with dry air. The temperature of the dry air is controlled by means of a heat exchanger to be equal to the temperature of the fluid circulating in the enclosure panels.

3.2 Spectrograph parameters

3.2.1 Plate scale and demagnification

The plate scale at the slit is equal to 4.44 arcsec/mm with the image derotator in the beam, or 4.51 arcsec/mm with it out of the beam.

The camera provides a demagnification factor along the slit (i.e. in the spatial direction) equal to the ratio of the focal lengths of the camera and collimator. Assuming no focal modifier lenses are in the beam, this is given by:

$$D_{spatial} = \frac{f_{collimator}}{f_{camera}} = \frac{2359}{700} = 3.37 \tag{3.1}$$

The demagnification factor perpendicular to the slit (i.e. in the spectral direction) is somewhat more complicated, since it is necessary to take into account the expansion of the beam caused by it not being normally incident on the echelle. The separation of the beam incident on the echelle and the reflected beam is 12.4 degrees, whilst the nominal blaze angle is 63.4 degrees; hence the angle of incidence is 57.2 degrees and the angle of reflection is 69.6 degrees. The demagnification factor is given by:

$$D_{spectral} = \frac{f_{collimator}}{f_{camera}} . \frac{cos(i)}{cos(r)} = \frac{2359}{700} . \frac{0.5417}{0.3486} = 5.24 \tag{3.2}$$

The plate scales at the slit, and at the detector both in the spatial and spectral directions, are summarised in Tab. 3.1. This assume that the focal modifier lenses are not used. An important number to remember is that *a slitwidth of 1 arcsec projects to 43 microns at the detector*, or about 2 detector pixels with an EEV CCD. This is often referred to as the 'matched slitwidth', since it is the minimum slitwidth which is properly sampled at the detector; using a larger slitwidth will degrade the instrumental resolution, whilst using a smaller slitwidth will result in the line profiles not being properly sampled. Clearly the matched slit will be different with different detectors.

Table 3.1: UES plate scales

	Without derotator	With derotator
Scale at slit (arcsec/mm)	4.51	4.44
Scale at detector (arcsec/mm):		
Spatial direction	15.20	14.96
Spectral direction	23.63	23.26

3.2.2 Echellogram parameters

The set of interference orders observable with UES is summarised in Tab. 3.2 for the 31.6 lines/mm echelle and in Tab. 3.3 for the 79.0 lines/mm echelle. For each order number, the tables give the follwing parameters:

- The central wavelength, the start and end wavelengths, and the Free Spectral Range.

- The linear dispersion.
- The cross-dispersion distances for the start, central and end wavelengths.
- The separation between adjacent orders.

The echellograms for the 31.6 g/mm and 79.0 g/mm echelles are shown schematically in Fig. 3.6. Further, in Chap. 10 a description of the planning software, ECHWIND is given. Briefly this software models UES and provides the user with information as to the detector coverage of the echellogram, with any detector at any specfied central wavelength.

Figure 3.6: In these digrams schematics of the echellograms for the 31.6 grooves/mm and 79.0 grooves/mm echelles are shown. Each line shows the Free Spectral Range in an echelle order; order numbers are given to the right of the orders and the corresponding central wavelengths (in Å) to the left. Also shown is the portion of the echellogram which can be recorded with a single exposure of the Tektronix CCD (24.6×24.6mm).

Table 3.2: UES echellogram: 31.6 echelle

```
Start of wavelength in Angstroms:      3000.00
End of wavelength in Angstroms:       11000.00
Ruling of echelle in lines per mm:     31.6046
"Ideal" blaze angle in degrees:         63.460
Beam separation in degrees:             12.417
Focal length of camera in mm:            700.0
Prism angle in degrees:                  54.03
Delta_theta in degrees:                  -1.49
```

NOTE: The "ideal" blaze is that which gives maximum light for theta=0.0 degrees

ORD	WAVEMIN (A)	WAVCENTR (A)	WAVEMAX (A)	FSR (A)	FSR (mm)	LD (A/mm)	CDMIN (mm)	CDCEN (mm)	CDMAX (mm)	ORSEP (mm)
189	3005.97	3013.94	3021.92	15.9	12.9	1.240	0.01	0.58	1.15	1.15
188	3022.00	3030.05	3038.11	16.1	12.9	1.247	1.16	1.73	2.29	1.14
187	3038.19	3046.34	3054.48	16.3	13.0	1.254	2.30	2.86	3.43	1.13
186	3054.56	3062.79	3071.02	16.5	13.1	1.260	3.43	3.99	4.55	1.12
185	3071.10	3079.42	3087.74	16.6	13.1	1.267	4.55	5.11	5.66	1.11
184	3087.81	3096.23	3104.64	16.8	13.2	1.274	5.67	6.22	6.77	1.10
183	3104.71	3113.22	3121.72	17.0	13.3	1.281	6.77	7.32	7.86	1.09
182	3121.79	3130.39	3138.99	17.2	13.4	1.288	7.87	8.41	8.95	1.08
181	3139.05	3147.75	3156.44	17.4	13.4	1.295	8.95	9.49	10.03	1.07
180	3156.51	3165.30	3174.09	17.6	13.5	1.303	10.03	10.57	11.10	1.07
179	3174.15	3183.04	3191.93	17.8	13.6	1.310	11.10	11.63	12.16	1.06
178	3191.99	3200.98	3209.98	18.0	13.7	1.317	12.16	12.69	13.21	1.05
177	3210.03	3219.12	3228.22	18.2	13.7	1.325	13.21	13.74	14.25	1.04
176	3228.27	3237.47	3246.67	18.4	13.8	1.332	14.26	14.78	15.29	1.03
175	3246.72	3256.02	3265.33	18.6	13.9	1.340	15.29	15.81	16.32	1.02
174	3265.38	3274.79	3284.20	18.8	14.0	1.348	16.32	16.83	17.33	1.02
173	3284.24	3293.76	3303.28	19.0	14.0	1.356	17.34	17.84	18.34	1.01
172	3303.33	3312.96	3322.59	19.3	14.1	1.363	18.35	18.85	19.35	1.00
171	3322.64	3332.38	3342.12	19.5	14.2	1.371	19.35	19.85	20.34	0.99
170	3342.17	3352.02	3361.88	19.7	14.3	1.379	20.34	20.83	21.32	0.98
169	3361.92	3371.90	3381.88	20.0	14.4	1.388	21.33	21.82	22.30	0.98
168	3381.92	3392.01	3402.11	20.2	14.5	1.396	22.30	22.79	23.27	0.97
167	3402.14	3412.36	3422.58	20.4	14.6	1.404	23.27	23.75	24.23	0.96
166	3422.61	3432.95	3443.29	20.7	14.6	1.413	24.23	24.71	25.19	0.95
165	3443.33	3453.79	3464.26	20.9	14.7	1.421	25.19	25.66	26.13	0.94

Explanation of abbreviations:
FSR: Free Spectral Range
LD: Linear dispersion at FSR centre
CD: Cross dispersion distance for wavemin, wavecentr and wavemax
ORSEP: Order separation

ORD	WAVEMIN (A)	WAVCENTR (A)	WAVEMAX (A)	FSR (A)	FSR (mm)	LD (A/mm)	CDMIN (mm)	CDCEN (mm)	CDMAX (mm)	ORSEP (mm)
164	3464.29	3474.88	3485.48	21.2	14.8	1.430	26.13	26.60	27.07	0.94
163	3485.51	3496.23	3506.96	21.4	14.9	1.439	27.07	27.54	28.00	0.93
162	3506.99	3517.84	3528.70	21.7	15.0	1.448	28.00	28.46	28.92	0.92
161	3528.73	3539.72	3550.72	22.0	15.1	1.457	28.92	29.38	29.84	0.91
160	3550.74	3561.87	3573.00	22.3	15.2	1.466	29.84	30.29	30.74	0.91
159	3573.03	3584.30	3595.57	22.5	15.3	1.475	30.75	31.20	31.64	0.90
158	3595.59	3607.01	3618.42	22.8	15.4	1.484	31.65	32.09	32.54	0.89
157	3618.44	3630.00	3641.56	23.1	15.5	1.494	32.54	32.98	33.42	0.88
156	3641.58	3653.29	3665.00	23.4	15.6	1.503	33.42	33.87	34.30	0.88
155	3665.02	3676.88	3688.74	23.7	15.7	1.513	34.30	34.74	35.17	0.87
154	3688.76	3700.77	3712.79	24.0	15.8	1.523	35.17	35.61	36.04	0.86
153	3712.80	3724.98	3737.15	24.3	15.9	1.533	36.04	36.47	36.89	0.86
152	3737.16	3749.50	3761.83	24.7	16.0	1.543	36.89	37.32	37.74	0.85
151	3761.84	3774.34	3786.84	25.0	16.1	1.553	37.74	38.17	38.59	0.84
150	3786.85	3799.51	3812.18	25.3	16.2	1.564	38.59	39.01	39.42	0.84
149	3812.19	3825.02	3837.86	25.7	16.3	1.574	39.42	39.84	40.25	0.83
148	3837.87	3850.88	3863.89	26.0	16.4	1.585	40.25	40.66	41.07	0.82
147	3863.89	3877.08	3890.27	26.4	16.5	1.596	41.07	41.48	41.89	0.82
146	3890.27	3903.64	3917.01	26.7	16.6	1.607	41.89	42.29	42.70	0.81
145	3917.01	3930.57	3944.12	27.1	16.8	1.618	42.70	43.10	43.50	0.80
144	3944.12	3957.87	3971.61	27.5	16.9	1.629	43.50	43.90	44.29	0.80
143	3971.61	3985.55	3999.48	27.9	17.0	1.640	44.29	44.69	45.08	0.79
142	3999.48	4013.61	4027.75	28.3	17.1	1.652	45.08	45.47	45.86	0.78
141	4027.74	4042.08	4056.41	28.7	17.2	1.663	45.86	46.25	46.64	0.78
140	4056.41	4070.95	4085.49	29.1	17.4	1.675	46.64	47.03	47.41	0.77
139	4085.48	4100.23	4114.98	29.5	17.5	1.687	47.41	47.79	48.17	0.76
138	4114.98	4129.94	4144.90	29.9	17.6	1.700	48.17	48.55	48.93	0.76
137	4144.90	4160.08	4175.26	30.4	17.7	1.712	48.93	49.30	49.68	0.75
136	4175.25	4190.66	4206.07	30.8	17.9	1.725	49.68	50.05	50.42	0.74
135	4206.06	4221.70	4237.33	31.3	18.0	1.737	50.42	50.79	51.16	0.74
134	4237.32	4253.19	4269.06	31.7	18.1	1.750	51.16	51.53	51.89	0.73
133	4269.05	4285.16	4301.27	32.2	18.3	1.764	51.89	52.26	52.62	0.73
132	4301.26	4317.61	4333.97	32.7	18.4	1.777	52.62	52.98	53.34	0.72
131	4333.95	4350.56	4367.16	33.2	18.5	1.790	53.34	53.69	54.05	0.71
130	4367.15	4384.01	4400.87	33.7	18.7	1.804	54.05	54.40	54.76	0.71
129	4400.86	4417.98	4435.10	34.2	18.8	1.818	54.76	55.11	55.46	0.70
128	4435.09	4452.48	4469.87	34.8	19.0	1.832	55.46	55.81	56.15	0.70
127	4469.85	4487.52	4505.19	35.3	19.1	1.847	56.15	56.50	56.84	0.69

Explanation of abbreviations:
FSR: Free Spectral Range
LD: Linear dispersion at FSR centre
CD: Cross dispersion distance for wavemin, wavecentr and wavemax
ORSEP: Order separation

ORD	WAVEMIN (A)	WAVCENTR (A)	WAVEMAX (A)	FSR (A)	FSR (mm)	LD (A/mm)	CDMIN (mm)	CDCEN (mm)	CDMAX (mm)	ORSEP (mm)
126	4505.17	4523.12	4541.07	35.9	19.3	1.861	56.84	57.19	57.53	0.68
125	4541.05	4559.29	4577.52	36.5	19.4	1.876	57.53	57.87	58.21	0.68
124	4577.50	4596.03	4614.57	37.1	19.6	1.891	58.21	58.54	58.88	0.67
123	4614.54	4633.38	4652.21	37.7	19.8	1.907	58.88	59.21	59.55	0.67
122	4652.19	4671.33	4690.48	38.3	19.9	1.922	59.55	59.88	60.21	0.66
121	4690.46	4709.92	4729.38	38.9	20.1	1.938	60.21	60.54	60.86	0.66
120	4729.35	4749.14	4768.93	39.6	20.2	1.954	60.86	61.19	61.51	0.65
119	4768.90	4789.03	4809.15	40.2	20.4	1.971	61.51	61.84	62.16	0.65
118	4809.12	4829.58	4850.05	40.9	20.6	1.988	62.16	62.48	62.80	0.64
117	4850.02	4870.84	4891.65	41.6	20.8	2.005	62.80	63.12	63.44	0.64
116	4891.62	4912.80	4933.97	42.4	20.9	2.022	63.43	63.75	64.06	0.63
115	4933.94	4955.49	4977.03	43.1	21.1	2.039	64.06	64.38	64.69	0.62
114	4977.00	4998.93	5020.85	43.9	21.3	2.057	64.69	65.00	65.31	0.62
113	5020.82	5043.13	5065.45	44.6	21.5	2.075	65.31	65.62	65.92	0.61
112	5065.42	5088.13	5110.85	45.4	21.7	2.094	65.92	66.23	66.53	0.61
111	5110.81	5133.94	5157.06	46.3	21.9	2.113	66.53	66.84	67.14	0.60
110	5157.03	5180.57	5204.12	47.1	22.1	2.132	67.14	67.44	67.74	0.60
109	5204.09	5228.07	5252.05	48.0	22.3	2.152	67.74	68.04	68.33	0.60
108	5252.01	5276.44	5300.87	48.9	22.5	2.171	68.33	68.63	68.92	0.59
107	5300.83	5325.71	5350.60	49.8	22.7	2.192	68.92	69.22	69.51	0.59
106	5350.56	5375.92	5401.28	50.7	22.9	2.212	69.51	69.80	70.09	0.58
105	5401.24	5427.08	5452.92	51.7	23.1	2.233	70.09	70.38	70.66	0.58
104	5452.88	5479.22	5505.57	52.7	23.4	2.255	70.66	70.95	71.24	0.57
103	5505.52	5532.38	5559.23	53.7	23.6	2.277	71.24	71.52	71.80	0.57
102	5559.19	5586.58	5613.96	54.8	23.8	2.299	71.80	72.09	72.37	0.56
101	5613.92	5641.85	5669.78	55.9	24.1	2.322	72.37	72.65	72.93	0.56
100	5669.73	5698.22	5726.71	57.0	24.3	2.345	72.92	73.20	73.48	0.56
99	5726.66	5755.73	5784.80	58.1	24.5	2.369	73.48	73.76	74.03	0.55
98	5784.75	5814.42	5844.08	59.3	24.8	2.393	74.03	74.31	74.58	0.55
97	5844.03	5874.31	5904.59	60.6	25.1	2.418	74.58	74.85	75.12	0.54
96	5904.54	5935.46	5966.37	61.8	25.3	2.443	75.12	75.39	75.66	0.54
95	5966.32	5997.89	6029.46	63.1	25.6	2.468	75.66	75.93	76.20	0.54
94	6029.40	6061.64	6093.89	64.5	25.9	2.495	76.20	76.46	76.73	0.53
93	6093.83	6126.77	6159.71	65.9	26.1	2.521	76.73	76.99	77.26	0.53
92	6159.66	6193.32	6226.98	67.3	26.4	2.549	77.26	77.52	77.78	0.53
91	6226.92	6261.32	6295.72	68.8	26.7	2.577	77.78	78.04	78.30	0.52
90	6295.67	6330.84	6366.01	70.3	27.0	2.605	78.30	78.56	78.82	0.52
89	6365.95	6401.91	6437.88	71.9	27.3	2.635	78.82	79.08	79.34	0.52

Explanation of abbreviations:
FSR: Free Spectral Range
LD: Linear dispersion at FSR centre
CD: Cross dispersion distance for wavemin, wavecentr and wavemax
ORSEP: Order separation

ORD	WAVEMIN (A)	WAVCENTR (A)	WAVEMAX (A)	FSR (A)	FSR (mm)	LD (A/mm)	CDMIN (mm)	CDCEN (mm)	CDMAX (mm)	ORSEP (mm)
88	6437.82	6474.61	6511.39	73.6	27.6	2.665	79.43	79.60	79.85	0.51
87	6511.33	6548.97	6586.61	75.3	27.9	2.695	79.85	80.11	80.36	0.51
86	6586.54	6625.06	6663.58	77.0	28.3	2.726	80.36	80.62	80.87	0.51
85	6663.51	6702.94	6742.37	78.9	28.6	2.759	80.87	81.12	81.37	0.51
84	6742.31	6782.68	6823.05	80.7	28.9	2.791	81.37	81.63	81.88	0.50
83	6822.98	6864.34	6905.69	82.7	29.3	2.825	81.88	82.13	82.38	0.50
82	6905.62	6947.98	6990.35	84.7	29.6	2.859	82.38	82.63	82.87	0.50
81	6990.28	7033.69	7077.11	86.8	30.0	2.895	82.87	83.12	83.37	0.50
80	7077.04	7121.55	7166.06	89.0	30.4	2.931	83.37	83.62	83.87	0.50
79	7165.98	7211.63	7257.27	91.3	30.8	2.968	83.87	84.12	84.36	0.49
78	7257.19	7304.01	7350.83	93.6	31.2	3.006	84.36	84.61	84.85	0.49
77	7350.75	7398.80	7446.84	96.1	31.6	3.045	84.85	85.10	85.35	0.49
76	7446.76	7496.08	7545.39	98.6	32.0	3.085	85.35	85.59	85.84	0.49
75	7545.31	7595.95	7646.59	101.3	32.4	3.126	85.84	86.09	86.33	0.49
74	7646.50	7698.52	7750.54	104.0	32.8	3.168	86.33	86.58	86.82	0.49
73	7750.45	7803.90	7857.35	106.9	33.3	3.212	86.82	87.07	87.31	0.49
72	7857.26	7912.21	7967.15	109.9	33.7	3.256	87.31	87.56	87.80	0.49
71	7967.06	8023.56	8080.07	113.0	34.2	3.302	87.80	88.05	88.30	0.49
70	8079.97	8138.10	8196.23	116.3	34.7	3.349	88.30	88.55	88.79	0.49
69	8196.13	8255.95	8315.78	119.7	35.2	3.398	88.79	89.04	89.29	0.50
68	8315.68	8377.27	8438.87	123.2	35.7	3.448	89.29	89.54	89.79	0.50
67	8438.77	8502.21	8565.66	126.9	36.3	3.499	89.79	90.04	90.29	0.50
66	8565.55	8630.94	8696.33	130.8	36.8	3.552	90.29	90.54	90.79	0.50
65	8696.21	8763.62	8831.04	134.8	37.4	3.607	90.79	91.04	91.30	0.51
64	8830.92	8900.45	8969.99	139.1	38.0	3.663	91.30	91.55	91.81	0.51
63	8969.86	9041.62	9113.38	143.5	38.6	3.721	91.81	92.07	92.32	0.52
62	9113.25	9187.34	9261.43	148.2	39.2	3.781	92.32	92.59	92.85	0.52
61	9261.30	9337.84	9414.38	153.1	39.8	3.843	92.85	93.11	93.37	0.53
60	9414.24	9493.35	9572.46	158.2	40.5	3.907	93.37	93.64	93.91	0.54
59	9572.31	9654.13	9735.94	163.6	41.2	3.973	93.91	94.18	94.45	0.54
58	9735.79	9820.45	9905.11	169.3	41.9	4.042	94.45	94.73	95.00	0.55
57	9904.94	9992.60	10080.25	175.3	42.6	4.112	95.00	95.28	95.56	0.56
56	10080.08	10170.89	10261.71	181.6	43.4	4.186	95.56	95.85	96.13	0.57
55	10261.53	10355.67	10449.81	188.3	44.2	4.262	96.13	96.43	96.72	0.58
54	10449.62	10547.28	10644.94	195.3	45.0	4.341	96.72	97.02	97.32	0.60
53	10644.74	10746.12	10847.50	202.8	45.8	4.422	97.31	97.62	97.93	0.61
52	10847.29	10952.60	11057.91	210.6	46.7	4.507	97.93	98.24	98.56	0.63

Explanation of abbreviations:

FSR: Free Spectral Range

LD: Linear dispersion at FSR centre

CD: Cross dispersion distance for wavemin, wavecentr and wavemax

ORSEP: Order separation

Table 3.3: UES echellogram: 79.0 echelle

```
Start of wavelength in Angstroms:      3000.00
End of wavelength in Angstroms:       11000.00
Ruling of echelle in lines per mm:     79.0115
"Ideal" blaze angle in degrees:         63.610
Beam separation in degrees:             12.417
Focal length of camera in mm:            700.0
Prism angle in degrees:                  54.03
Delta_theta in degrees:                  -0.35
```

NOTE: The "ideal" blaze is that which gives maximum light for theta=0.0 degrees

ORD	WAVEMIN (A)	WAVCENTR (A)	WAVEMAX (A)	FSR (A)	FSR (mm)	LD (A/mm)	CDMIN (mm)	CDCEN (mm)	CDMAX (mm)	ORSEP (mm)
75	2992.98	3013.06	3033.15	40.2	31.2	1.286	0.00	1.47	2.89	2.89
74	3033.34	3053.98	3074.61	41.3	31.7	1.303	2.91	4.34	5.74	2.83
73	3074.79	3096.00	3117.21	42.4	32.1	1.321	5.75	7.15	8.52	2.77
72	3117.37	3139.17	3160.97	43.6	32.5	1.339	8.54	9.91	11.25	2.72
71	3161.12	3183.54	3205.96	44.8	33.0	1.358	11.26	12.61	13.93	2.66
70	3206.10	3229.17	3252.23	46.1	33.5	1.378	13.94	15.26	16.55	2.61
69	3252.36	3276.10	3299.84	47.5	34.0	1.398	16.55	17.85	19.11	2.56
68	3299.95	3324.39	3348.84	48.9	34.5	1.419	19.12	20.39	21.62	2.51
67	3348.94	3374.12	3399.30	50.4	35.0	1.440	21.63	22.87	24.09	2.46
66	3399.39	3425.34	3451.29	51.9	35.5	1.462	24.09	25.31	26.50	2.41
65	3451.37	3478.12	3504.88	53.5	36.1	1.484	26.50	27.69	28.86	2.36
64	3504.94	3532.54	3560.14	55.2	36.6	1.507	28.86	30.03	31.17	2.31
63	3560.20	3588.68	3617.16	57.0	37.2	1.531	31.17	32.32	33.44	2.26
62	3617.21	3646.62	3676.02	58.8	37.8	1.556	33.44	34.56	35.66	2.22
61	3676.06	3706.44	3736.82	60.8	38.4	1.582	35.66	36.76	37.83	2.17
60	3736.85	3768.25	3799.65	62.8	39.1	1.608	37.83	38.91	39.96	2.13
59	3799.67	3832.15	3864.62	65.0	39.7	1.635	39.96	41.02	42.04	2.08
58	3864.63	3898.23	3931.84	67.2	40.4	1.663	42.04	43.08	44.09	2.04
57	3931.84	3966.63	4001.43	69.6	41.1	1.693	44.09	45.10	46.08	2.00
56	4001.42	4037.47	4073.52	72.1	41.8	1.723	46.08	47.08	48.04	1.96
55	4073.50	4110.87	4148.24	74.7	42.6	1.754	48.04	49.01	49.96	1.92
54	4148.21	4186.98	4225.75	77.5	43.4	1.787	49.96	50.91	51.84	1.88
53	4225.72	4265.96	4306.21	80.5	44.2	1.820	51.84	52.77	53.67	1.84
52	4306.16	4347.97	4389.78	83.6	45.1	1.855	53.67	54.59	55.47	1.80
51	4389.72	4433.19	4476.65	86.9	46.0	1.892	55.47	56.37	57.24	1.76
50	4476.59	4521.81	4567.03	90.4	46.9	1.929	57.23	58.11	58.96	1.73

Explanation of abbreviations:

```
FSR:    Free Spectral Range
LD:     Linear dispersion at FSR centre
CD:     Cross dispersion distance for wavemin, wavecentr and wavemax
ORSEP:  Order separation
```

ORD	WAVEMIN (A)	WAVCENTR (A)	WAVEMAX (A)	FSR (A)	FSR (mm)	LD (A/mm)	CDMIN (mm)	CDCEN (mm)	CDMAX (mm)	ORSEP (mm)
49	4566.96	4614.04	4661.12	94.2	47.8	1.969	58.96	59.82	60.65	1.69
48	4661.04	4710.11	4759.17	98.1	48.8	2.010	60.65	61.49	62.30	1.66
47	4759.09	4810.26	4861.43	102.3	49.9	2.053	62.30	63.13	63.92	1.62
46	4861.34	4914.76	4968.18	106.8	50.9	2.097	63.92	64.73	65.51	1.59
45	4968.08	5023.90	5079.72	111.6	52.1	2.144	65.51	66.30	67.07	1.56
44	5079.61	5138.00	5196.38	116.8	53.3	2.192	67.06	67.84	68.59	1.52
43	5196.26	5257.40	5318.53	122.3	54.5	2.243	68.59	69.35	70.08	1.49
42	5318.40	5382.48	5446.56	128.2	55.8	2.297	70.08	70.82	71.54	1.46
41	5446.42	5513.66	5580.90	134.5	57.2	2.353	71.54	72.27	72.98	1.44
40	5580.75	5651.39	5722.03	141.3	58.6	2.411	72.98	73.69	74.38	1.41
39	5721.88	5796.19	5870.50	148.6	60.1	2.473	74.38	75.09	75.77	1.38
38	5870.33	5948.60	6026.87	156.5	61.7	2.538	75.76	76.46	77.12	1.36
37	6026.68	6109.24	6191.80	165.1	63.3	2.607	77.12	77.80	78.46	1.34
36	6191.60	6278.81	6366.02	174.4	65.1	2.679	78.46	79.12	79.77	1.31
35	6365.81	6458.06	6550.32	184.5	67.0	2.756	79.77	80.43	81.06	1.30
34	6550.10	6647.86	6745.62	195.5	68.9	2.837	81.06	81.71	82.34	1.28
33	6745.38	6849.15	6952.93	207.6	71.0	2.923	82.34	82.98	83.60	1.26
32	6952.66	7063.02	7173.38	220.7	73.2	3.014	83.60	84.24	84.86	1.25
31	7173.10	7290.69	7408.28	235.2	75.6	3.111	84.85	85.49	86.10	1.24
30	7407.97	7533.52	7659.08	251.1	78.1	3.215	86.10	86.73	87.34	1.24
29	7658.74	7793.10	7927.47	268.7	80.8	3.325	87.34	87.97	88.58	1.24
28	7927.09	8071.22	8215.35	288.3	83.7	3.444	88.58	89.21	89.82	1.25
27	8214.93	8369.93	8524.92	310.0	86.8	3.571	89.82	90.46	91.08	1.26
26	8524.45	8691.60	8858.75	334.3	90.1	3.709	91.07	91.72	92.35	1.28
25	8858.22	9039.00	9219.78	361.6	93.7	3.857	92.35	93.01	93.65	1.30
24	9219.18	9415.33	9611.48	392.3	97.6	4.018	93.65	94.33	94.99	1.34
23	9610.80	9824.37	10037.94	427.1	101.9	4.192	94.99	95.69	96.38	1.39
22	10037.15	10270.57	10503.99	466.8	106.5	4.382	96.37	97.11	97.83	1.46
21	10503.06	10759.23	11015.40	512.3	111.6	4.591	97.83	98.61	99.38	1.55

Explanation of abbreviations:

FSR: Free Spectral Range
LD: Linear dispersion at FSR centre
CD: Cross dispersion distance for wavemin, wavecentr and wavemax
ORSEP: Order separation

3.2.3 Spectral resolution

The instrument provides slit-limited resolution over the entire camera field and over the entire wavelength range. This means that the resolution is limited not by the point-spread-function of the spectrograph optics, but by the detector pixel size; the wavelength resolution is equal to the spectrograph dispersion multiplied by the spatial resolution of the detector.

For a CCD the spatial resolution of the detector is determined entirely by sampling considerations, and can be considered equal to two detector pixels. The situation is more complex for the IPCS, where the detector point spread function may be significant compared to the pixel size (see the IPCS-II User manual).

The detectors which might be used with UES currently include EEV and Tektronix CCDs, with pixel sizes of 22.5 μm and 24 μm respectively, and the IPCS-II providing a spatial resolution of 30 μm. The resolving power for each of these detectors is summarised in Tab. 3.4, obtained by combining these numbers with the linear dispersion given in Tabs. 3.3 and 3.2). The resolution in km/s is also given. Both of these numbers are independent both of the wavelength, and the echelle being used. The resolution in Angstroms will of course vary with wavelength, and the table gives figures at a few representative wavelengths.

Table 3.4: UES resolving power and velocity resolution

Detector	Spatial resolution (μm)	Resolving power	Velocity resolution (km s^{-1})	Wavelength resolution (Å) 3000 Å	6000 Å	10000 Å
EEV CCD	45	52,000	5.77	0.058	0.115	0.192
Tek CCD	48	49,000	6.12	0.061	0.122	0.204
IPCS-II	30	78,000	3.85	0.038	0.077	0.128

3.2.4 Spectral range

The spectrograph is designed to be usable over the range from 3000 Åto 1.1 μm. However, it is unfortunately not possible to cover this entire range at once. Tabs. 3.2 and 3.3 summarise the free spectral range and order separation at a variety of wavelengths, and can be used to calculate the number of orders that will fit on the detector simultaneously, and to check whether the detector can cover the entire length of the orders. This is discussed in more detail in Section 3.3. Additionally the STARLINK released programme ECHWIND (see Starlink User Guide No. ??) gives a graphical representation of the detector coverage of the echellogram at any particular echelle central wavelength. (see also Chap. 10.)

3.2.5 Field of view

When the spectrograph is used with the cross-dispersing prisms and the 31.6 lines/mm echelle, the minimum order separation on the detector is 0.49 mm (7.3 arcsec). This limits the slit length to less than about 6 arcsec, otherwise adjacent spectral orders will overlap. This cross-dispersing mode of operation is therefore primarily useful for objects which are close to being point sources. Even for these objects it may not be possible to obtain a good sky subtraction. As discussed in more detail in section 3.3, improved sky subtraction can be obtained by using the 79.0 echelle, which gives a minimum order separation of 1.24 mm (18.5 arcsec).

It is possible to use the full 5 arcmin length of the slit, in order to carry out long slit spectroscopy of extended objects. However, in this case it is no longer possible to use the cross-dispersers. The wavelength range is limited to one spectral order, and other orders must be suppressed by an appropriate narrowband blocking filter.

3.3 Principles of operation (cross–dispersed mode)

In order to configure the spectrograph for any given observation it is necessary to specify the following parameters:

- Choice of echelle grating
- Central wavelength and order number
- Slit width and length

The rest of this section dicusses these parameters in more detail.

3.3.1 Choice of echelle grating

A choice of two gratings is provided with UES, one with 31.6 lines/mm and one with 79.0 lines/mm. It is important to realise that the choice of grating is not determined by the spectral resolution required, as in a conventional first order spectrograph such as ISIS. Instead, the choice of grating is determined by a trade-off between wavelength coverage and the quality of sky subtraction.

In order to see why this is the case, its worth briefly restating the basic equations governing diffraction by a grating. The grating equation describes the condition for constructive interference:

$$\frac{m.\lambda}{d} = sin(i) + sin(\theta) \tag{3.3}$$

m	=	Interference order
λ	=	Wavelength
d	=	Spacing between lines on grating
i	=	Angle of incidence of light
θ	=	Angle of reflection for constructive interference

The angular dispersion is obtained by differentiating this:

$$\frac{d\theta}{d\lambda} = \frac{sin(i) + sin(\theta)}{\lambda.cos(\theta)} \tag{3.4}$$

The dispersion is a function only of the angles at which the grating is used, and not a function of the groove spacing. The two UES gratings have nearly the same blaze angle (64.95 degrees for the 31.6 echelle and 63.96 degrees for the 79.0 echelle), and hence are used with similar values of i and θ. This means that at a given wavelength they provide almost identical spectral resolution as can be seen from Tabs. 3.2 and 3.3.

The difference between the two gratings is that, at any given wavelength, the grating equation implies they must be operated at a different interference order. For example, observations at 5000Å would use either the 31.6 lines/mm grating in order m $\approx$ 114, or the 79.0 lines/mm grating in order m $\approx$ 45 (see Tabs. 3.2 and 3.3). The principal effect of this is that the wavelength range of each order, normally referred to as the Free Spectral Range (FSR) is different. The FSR is given by:

$$FSR = \frac{\lambda}{m} \tag{3.5}$$

At any given wavelength, the 79.0 lines/mm grating will have 2.5 times the free spectral range of the 31.6 lines/mm grating; the orders are 2.5 times longer, and hence 2.5 times further apart. Since the dispersion is the same, this means that for a fixed detector size, the 79.0 lines/mm grating provides less wavelength coverage, but more space between the orders to measure the sky background.

When deciding which echelle to use, it is therefore necessary to consider how long a slit you need to get adequate sky subtraction, and how many exposures will be required to cover the required wavelength range.

The inter-order spacing with both echelles at various wavelengths is summarised in Tab. 3.5. This assumes no focal modifier lenses are in the beam. The slitlength used should be slightly shorter than this inter-order spacing, in order to leave a gap between the orders.

Table 3.5: Interorder spacing with UES echelles

Wavelength (Å)	Interorder spacing (arcsec) (arcsec)	
	31.6 echelle	79.0 echelle
3000	17	43
3500	14	34
4000	12	29
5000	9.3	23
6000	8.1	20
7000	7.5	19
8000	7.5	19
9000	7.8	20
10000	8.6	22
11000	9.6	24

It is possible to estimate the number of exposures required to cover a given wavelength range using the data in Tabs. 3.2 and 3.3. These tables give the length and separation on the detector of each order.

This calculation can be carried out much more easily using graphical means, and the ECHWIND programme has been developed for this purpose. ECHWIND draws a complete echellogram on an image display, together with a box representing the size and shape of the detector in use. The position of individual spectral lines can also be marked on the display. The user can then move the detector window around using the mouse. At each position, the screen displays the minimum and maximum wavelengths and order numbers falling on the detector. The position of the detector window can be marked on the screen so as to ease preparation of observations where multiple overlapping wavelength ranges are required. The output of the programme is the central wavelength and order number of each exposure.

3.3.2 Central wavelength and order number

Having decided which central wavelengths are to be observed, it is then necessary to configure the spectrograph by moving the following mechanisms:

- The echelle angle θ. Changing this angle changes the position of the echellogram on the detector in the dispersion direction.
- The echelle angle γ. Changing this angle changes the position of the echellogram on the detector in the cross-dispersion direction.
- The prism translation. Moving the echelle grating changes the direction in which it sees the cross-dispersing prisms, and the prism assembly has to be moved (and rotated) to correct for this.
- The slit angle. In order to keep the projected slit at the same orientation on the detector, the slit angle has to be rotated as a function of wavelength.
- The collimator. There is a choice of two collimators, one coated for the UV (less than 4000 Å) and one with a wideband coating. When changing wavelength it is necessary to select the appropriate collimator.
- The colimator focus. When a different collimator is selected, it is necessary to apply an offset to the collimator focus, this is automatically calulated and applied by the UES control software.

The instrument control software contains a model of the spectrograph, which takes as input the central wavelength and order number required by the observer, and configures the spectrograph as described above. It is possible for the observer not to specify the order number, in which case the software will determine the interference order for which the wavelength selected is closest to blaze.

3.3.3 Slit width

When deciding on what slitwidth to use, the starting point is to determine the size of the 'matched slit'. As discussed in section 3.2.1, this is the slitwidth which corresponds to the spatial resolution of the detector; in the case of a CCD, it is the slitwidth which projects to two detector pixels. The matched slit is therefore the minimum slitwidth which is properly sampled at the detector; using a larger slitwidth will degrade the instrumental resolution, whilst using a smaller slitwidth will result in the line profiles not being properly sampled. The matched slit with different detectors is summarised in Tab. 3.6. The figures in arcseconds have been calculated assuming the derotator is in the beam, and assuming no focal modifier lenses are being used.

Table 3.6: UES matched slit

Detector	Spatial resolution	Matched slit	
	μm	μm	arcsec
EEV CCD	45	236	1.05
Tek CCD	48	252	1.12
IPCS-II	30	157	0.70

In conditions of poor seeing it may be sensible to open up the slit, trading poorer resolution for improved throughput. For example, the IPCS-II can provide higher spectral resolution than the CCD, but at the cost of increased slit losses; if spectral resolution is less important than throughput, it may be sensible to use a 1 arcsecond slit with the IPCS-II.

Chapter 4

The Derotation Optics

4.1 The need for a derotator

The altazimuth design of the telescope means that the field of view rotates as the telescope tracks. It is necessary to compensate for this in order that:

- The spectrograph slit can be set to a constant PA on the sky (mainly of use for extended objects).
- Autoguiding can be carried out using offset guide stars.

At Cassegrain the approach taken is to mount instruments on a turntable, and physically rotate them so as to keep the final image at a fixed orientation. This approach is not possible with heavy instruments such as UES; instead an optical image derotator is used. This allows the instrument to remain stationary, at the cost of reduced field and throughput.

It is possible to observe either with or without the derotator in the beam. Inserting or removing the derotator is a fairly major change; it has to be carried out during the daytime, and advance notice is required. *In normal operation UES is used with the derotator.*

(N.B. Polarimetry, when implemented, must be done without the derotator and hence will be limited to point sources)

4.2 Design

The image derotator is illustrated in Fig. 4.1. It consists of a flat mirror and a pair of fused silica prisms, each with lens surfaces. The detailed specification of the derotation optics is given in La Palma Technical Note 9.

The incoming beam from the telescope undergoes total internal reflection in the first prism, and emerges travelling in a direction close to perpendicular to the telescope axis. The beam is then reflected by the flat mirror back towards the second prism, where it again undergoes total internal reflection, and emerges travelling parallel to the telescope axis. The lens surfaces on the prisms extend the optical path, so that the position of the focal plane remains constant, and maintain good image quality.

The orientation of the output image is altered by rotating the whole assembly about the telescope axis.

Rotating the derotation optics through a given angle has the effect of rotating the final image through twice that angle. Note that the derotation optics also has the effect of changing the image parity (i.e. the image field is mirrored as seen at the detector). In normal operation the unit is rotated by the telescope control system at an appropriate rate to keep the final image at a fixed orientation, the orientation required being specified by the observer.

4.3 Specification

4.3.1 Throughput

At UV and visible wavelengths, losses in the derotation optics arise as a result of the four air-glass surfaces (2 per cent loss at each surface) and the reflection at the flat aluminium mirror (approx 15 per cent loss). The throughput of the system is therefore expected to be about 75 per cent, with the losses dominated by the reflection at the flat mirror.

The throughput of the system cuts off sharply in the near infrared, beyond about 2 microns, due to absorption by the fused silica material (Heraeus Homosil) used in constructing the prisms. This material also absorbs at wavelengths between 1.3 and 1.5 microns. It transmits well in the UV down to below the atmospheric cutoff at 3000Å.

It is worth noting that the losses in the WHT derotation optics are significantly greater than those in the optical derotator used with UCLES (in principle an echelle of similar design to UES) at the AAT. The smaller field and longer f/ratio at the AAT makes it possible to construct a monolithic derotator, in which the reflection at the flat mirror is replaced by a third total internal reflection. The only losses in the AAT derotator are therfore those due to the two air-glass surfaces on the two external faces. Unfortunately, it is not possible to adopt a similar approach on the WHT, due to the larger field and faster f/ratio. The advantage however with the derotator for UES, is that due to the larger field, offset autoguiding is possible.

4.3.2 Field of view

The unvignetted field of view of the derotation optics has a diameter of 2.5 arcmin. The full field of view is 5 arcmin in diameter, with vignetting of 50 per cent at the edge of the field.

4.3.3 Image quality

Spot diagrams for the theoretical design of the Nasymth image derotator are reproduced in La Palma Technical Note 9.

The diagrams show some transverse chromatic aberration, giving a slightly larger image scale at longer wavelengths. If the images from 3300 to 10000Å are superimposed, these will make a line of about 0.7×0.2 arcsec in a radial direction. This has two effects:

- The scale along the slit will vary very slightly with wavelength. The variation in scale over the entire wavelength range is of order 1 per cent. This may be relevant for some longslit spectroscopy.
- Offset guide stars may appear to be elongated when viewed in white light.

Figure 4.1: Schematic of UES derotator

Chapter 5

The nasmyth A&G Unit

5.1 A&G unit design

5.1.1 Overview

The layout of the A&G unit is shown in Fig. 5.1. This unit is arguably the most complex part of the observing system to understand. This is because a number of different light-paths exist, in order to support different A&G functions, and these have to fit into a very small space envelope. This situation can be contrasted with the spectrograph itself, where there is just one lightpath, and far more relaxed space constraints. The following light-paths exist within the A&G:

- The main beam from the telescope to the spectrograph slit
- The return beam from the spectrograph slit to the acquisition TV
- The return beam from the spectrograph slit to the CCD autoguider, for guiding on the slit image.
- The beam from the telescope to the CCD autoguider, for offset guiding.
- The beam from the calibration unit to the spectrograph slit.

In the next few subsections, a description of each of the lightpaths is given, along with instructions on how to select them. Finally, how the system is expected to be used in practice is described.

> *An upgrade of the UES A&G unit is in progress at the time of writing and should come into use in mid–late 1994. The upgraded A&G unit will have higher throughput enabling guiding on objects down to ≈17 mag. In section 5.1.8 details of the enhancements are given.*

5.1.2 Lightpath selection

Moving along the main beam from the telescope to spectrograph slit, the first component encountered in the A&G unit is the autoguider mirror. This has a pivotal role in the operation of the A&G unit, since which of the possible lightpaths is operational is determined primarily by moving the mirror.

Figure 5.1: The Nasymth A&G unit

The mirror is inclined at an angle of 45 degrees to the lighpath, so that light coming from the telescope and intercepted by the mirror is directed downwards. This light comes to a focus below the mirror, in what is normally referred to as the 'reflected focal plane'; this reflected focal plane is used for acquisition and guiding, as described in section 5.1.4. Holes are cut in the mirror, in order to allow the central part of the beam to pass through the mirror and reach the spectrograph, as described in section 5.1.3; in normal operation the inner part of the field, which contains the object being observed, is therefore visible at the slit, whilst light from the outer part of the field is directed to the reflected focal plane for offset autoguiding.

The size of the hole in the autoguider mirror determines the field of view visible at the slit. There are three holes with different sizes, giving different tradeoffs between field of view at the slit and the amount of field available in the reflected focal plane for autoguiding. The required hole is selected by moving the mirror. It is also possible to move the mirror to a position with no hole, where all the light is directed to the reflected focal plane, and to a clear position where all the light reaches the spectrograph slit.

These options are summarised in Tab. 5.1. This gives the unvignetted and partially vignetted field of view at available at the slit for each of the options. Fig. 5.2 shows plots of the vignetting along the slit produced by the autoguider mirror in the different positions.

Table 5.1: Autoguider mirror options

Autoguider mirror position	Unvignetted field diameter at slit (arcsec)	Partially vignetted field diameter at slit (arcsec)	Field at reflected focal plane (arcsec^2)
GUIDEONLY	0	0	
POINTSOURCE	18	170	
SHORTSLIT	73	213	
LONGSLIT	161	271	
CLEAR	161	271	

In addition to these options, there are two furtherpositions for the autoguider mirror. One of the autoguider mirrors is a mirror which, if selected (see ICL command `UMIRROR ULAMPS`), directs light from the calibration unit into the spectrograph (see section 5.1.7). When the autoguider is moved to its other extreme position, the return light path to the acquisition TV is clear (see sec. 5.1.6 and also ICL command `UTVVIEW`).

5.1.3 Main beam from telescope to spectrograph

After passing through the autoguider mirror, the main beam from the telescope passes through three filter wheels before reaching the slit–unit of the spectrograph. The three filter wheels are intended for colour filters, neutral density filters, and auxiliary components such as polarisers.

Each filter wheel contains 11 positions, of which position 1 is always empty. The maximum filter diameter is 80 mm. The rear filter wheel, intended for colour filters, can accomodate filters up to 25 mm in thickness, the front wheel, intended for auxiliary components, can accomodate components up to 15 mm in thickness, whilst the central wheel, intended for neutral density filters, can accomodate filters up to 10 mm in thickness.

The filters normally loaded in the colour and neutral density filter wheels are summarised in Tabs. 2.7 and 2.8. Transmission curves for the filters are shown in Figs. A.1 and A.2. These filters are of differing

Figure 5.2: Vignetting caused by autoguider mirror

thickness and hence the WHT telescope focus must be adjusted according to the filter combinations inserted into the beam, and also the autoguider probe focus must be adjusted to compensate for the this change in the reflected focal plane.

> *At present (1994) the main beam neutral density filters introduce an unacceptable amount of ripple and hence their use is discouraged.*

It is possible for observers to bring non-standard filters for 'special' applications, but at least one months advance notice is required, since it will generally be necessary to manufacture special adapters in order to be able to mount the filters.

Filters are loaded by means of an access hatch in the side of the A&G unit; however, this is a delicate operation and must only be carried out by properly trained staff—this is a daytime operation. Having changed a filter, the name of filter must be input to the system computer using the `UNAMES` command. (It is eventually intended that the system computer will automatically be able to determine the filters in use by means of the bar-coding the filters—check with your Support Astronomer for the progress on this feature.)

At the point where the main beam enters the A&G unit from the derotation optics is a dark slide. This should be kept closed except when observing, to protect the optics from dust.

N.B. Remember—the WHT focus must be adjusted to compensate for the total thickness of glass of the filter combinations in use.

5.1.4 Beam from telescope to CCD autoguider

As noted in section 5.1.2, the beam from the telescope to the CCD autoguider comes to a focus in the reflected focal plane below the autoguider mirror. In that reflected focal plane are two autoguider probes. Each probe consists of a small prism feeding a fibre image-guide, which transfers an image to the CCD autoguider, mounted on top of the A&G unit. The two probes, normally referred to as the 'coarse' and 'fine' guide probes, give different scales and field of view. The coarse probe provides a field of 13 arcsec (3 mm) and a scale at the CCD autoguider of 0.27 arcsec/pixel. The fine probe provides a field of 4.4 arcsec (1 mm) and a scale at the CCD autoguider of 0.13 arcsec/pixel. The fine fibre is UV transmitting, for guiding in the UV, the coarse fibre is not. The larger field of the coarse probe means that this is more useful for most applications. The fine probe is only useful for acquisition and guiding in the UV, or in conditions of superlative seeing.

The autoguider probes are mounted on an (x,y) table, making it possible to move them around the reflected focal plane in order to pick up the image of a potential guide star. The probes can be positioned in steps of 20 μm (about 0.09 arcsec). The probes can also be moved in the z direction in order to focus the image. The stepsize for the focus movement is 53 μm; one z–step gives a change in image-size of about 0.02 arcsec.

N.B. Remember—when filters are used in the main beam, and the WHT focus is adjusted to take account of this, the autoguider focus must also be adjusted to compensate for the change in WHT focus.
It is planned to fully automate this process of focus compensation before 1995, but for the present it must be done manually.

During object acquisition, the coarse probe is used to view the field at the rotator centre, with the autoguider mirror positioned so that all the light from the telescope is directed down into the reflected focal plane. During an exposure, either guide probe might be used for autoguiding on an offset guide star in the outer part of the field.

The light from the autoguider probes can be independently filtered, by means of a 12 position filter wheel. The autoguider filters are permanently mounted, and are summarised in Tab. 2.9. All filters are 2 mm thick, including the fused silica filter in the clear position. Transmission curves are shown in Fig. A.3.

The optical path which transfers the image output from the fibres to the CCD autoguider is fairly complex. It is summarised here for information only; see the nasmyth A&G Unit optics manual for a more detailed description. The output from the coarse fibre is first redirected by a 45 degree mirror, then bought to a focus in an intermediate focal plane by a pair of achromats. The outputs from the fine fibre and the slitviewing fibre (see section 5.1.4) also appear in the intermediate focal plane, injected into the lightpath by means of prisms on the ends of the fibres. The intermediate focal plane therefore contains images of all three fibre outputs, slightly offset from one another. This combined image is then passed through the autoguider filter wheel, and finally reimaged onto the CCD autoguider by means of two off-axis paraboloids.

Which guide probe is used is determined by reading out only a small window of the CCD autoguider, containing the image of the desired probe. The CCD autoguider can be used in two modes:

- When being used for target acquisition, the autoguider CCD can be switched into a mode where the CCD window corresponding to one of the guide probes is continuously read out. The target can then be centred on the probe.
- When being used for autoguiding, the procedure is first to read out the entire autoguider CCD. The autoguider software will then search for suitable guide stars in any of the windows. The observer can then ask the autoguider to start generating guide errors by centroiding on one of these stars.

5.1.5 Return beam from slit to CCD autoguider

The image reflected from the centre of the slit jaws can be viewed on the CCD autoguider by means of a fibre-optic image guide, identical to the fine guide probe discussed in section 5.1.4 (i.e. field of view of 4.4 arcsec, scale of 0.13 arcsec/pixel, UV transmitting), except that this fibre is fixed in position. The light is filtered by the autoguider filter wheel, exactly as for the two guide probes.

The optical path which transfers the image to the CCD autoguider is fairly complex. It is summarised here for information only; see the nasmyth A&G Unit optics manual for a more detailed description. A mirror supported by a spider is used to view the central part of the slit jaws. The image is relayed by this mirror and a UV–triplet lens to a prism on the input end of the fibre image guide. This whole assembly is supported by the slit–unit, so moves with the slit, and so can be used at any slit–angle. The output of the slitviewer fibre image guide is combined with the output from the guide fibres, and re-imaged onto the CCD autoguider, as summarised in section 5.1.4.

5.1.6 Return beam from slit to acquisition TV

The slitviewer fibre image guide gives only a very small field of view. This is adequate for verifying that the object remains on the slit during an exposure, but is not adequate for target acquisition. An additional means of viewing the entire field at a very coarse scale on an acquisition TV is therefore provided. The scale is about 1.14 arcsec/pixel in the X direction on the TV, and about 0.73 arcsec/pixel in the Y direction. This option cannot be used whilst an exposure is active.

In order to use the acquisition TV to view the field, it is neccesary to do three things:

- The autoguider mirror must be moved so that the TV pickoff mirror views the slit. The image of the slit jaws is then relayed to an ISEC intensified TV mounted on top of the A&G unit.

- Unlike the fibre slitviewer, the pickoff mirror for the acquisition TV is not attached to the slit unit, and so does not move with the slit; in order for the return beam from the slit to reach the pickoff mirror, the slitangle *must* be set to zero degrees.
- The return beam from the slit to the pickoff mirror has to pass through the main filter wheels; in order to make this possible, the filter wheels must all be moved to position 1, so that the beam can pass through specially cut holes in the wheels.

Even once these actions have been carried out, the field of view of the TV will still be obstructed; the slit-viewing probe obstructs both the beam from the telescope to the slit, and the return beam from the slit to the pickoff mirror. Fig. 5.3 is a sketch of the TV field, showing the following features:

- The slit itself appears vertical on the TV, running from top to bottom of the image.
- There is an obstruction in the centre of the field, preventing the TV from viewing the central part of the slit. This obstruction is the slit viewing probe (see below), with its 3 support vanes. Since the slitviewing probe and TV both view the slit from the same angle, it is inevitable that the slitviewing probe obstructs the central part of the TV field.
- There is a further obstruction close to the lower right-hand edge of the TV field. This obstruction is again the slit-viewing probe, but this time obstructing the beam from the telescope to the slit, rather than the return beam from the slit to the TV.
- The dekker slide appears in front of the slit jaws, and contains a dekker mask designed to restrict the slitlength. The shape of the dekker mask (normally referred to as the 'concorde' dekker) is illustrated in Fig. 3.2. It moves across the TV field from right to left, with the narrow end of the dekker appearing on the right–hand side. Fig. 5.3 shows the appearance of the TV field with this dekker mask in different positions.

In order to use the TV to view the slitjaws, it is first necessary to move the dekker mask out of the way, by moving it to close to the top end of its range of movement.

Since the central part of the TV field is obstructed, it is not possible to use the TV to centre an object on the slit directly. After pointing the telescope at a new object, the normal procedure is to apply a standard aperture offset. This will offset the telescope so that the object appears in an unobstructed part of the TV field. The object can be centred up, and the aperture offset then removed to place the object back on the slit. [1]

5.1.7 Beam from calibration unit to spectrograph

The calibration unit is a separate unit mounted to one side of the main A&G unit. Light from the calibration unit enters the A&G unit via a bellow–like interface, and is injected into the main beam to the spectrograph by means of a 45 degree mirror mounted on the end of the autoguider mirror.

At the end of the calibration unit furthest from the A&G is a set of six lamphouses arranged in a fan. Four of these lamphouses currently contain lamps; ThAr and FeAr lamps for wavelength calibration, and Tungsten and Deuterium lamps for flatfields. In normal use the ThAr is the lamp of choice for wavelength calibration, and the Tungsten lamp for flatfields. The lamps are driven by the same type of constant–current power supply as used at Cassegrain; these are mounted in the A&G electronics rack.

Notes:

[1] For higher centering accuracy, place the autoguider probe at its central position (ICL command `UAGXY 35540 41200`). Then centroid on the star, move the image to a standard position previously calculated to correspond to the centre of the slit in both directions. By repeating this procedure with a temporarily closed shutter (use the ICL `PAUSE UES` command followed by `CONTINUE UES`), proper tracking can be checked during the exposure.

Figure 5.3: Field of acquisition TV

Each lamphouse has a shutter, so that it is possible in principle to leave the lamp on for it to stabilise before using the lamp. In practice this is not done, due to the limited lifetime of the lamps.

In normal operation, the light from each lamp is fed via condensor lenses into a 6–input, 1–output fibre–optic lightguide, the output from which is randomised. This fibre-optic mixer makes it possible to use as many lamps as desired simultaneously. The output of the fibre-optic mixer is re-imaged by a transfer lens to form the system pupil. At this pupil it is possible to locate a diffuser and an aperture mask, which mimic the pattern of illumination of the telescope pupil (in particular, the secondary obstruction). Another lens re-images this pupil model to form a virtual image at the same distance as the telescope pupil.

There is a choice of two diffusers, one for UV work and one for broadband work. In practice, the diffuser greatly reduces the throughput of the calibration system, and is often moved out of the beam completely. Under these circumstances the pupil of the calibration system does *not* fully mimic that of the telecope. Note that the diffuser cannot be moved under computer control; it must be moved manually, and only by a properly trained member of staff.

There are two other means, less frequently used, for increasing the intensity of the calibration source. It is not possible to select either of these options under computer control; they must be set–up by a properly trained member of staff.

- Instead of re-imaging the ouput of the mixer onto the diffuser, it is possible to use a condensor to concentrate the light onto the centre of the slit. When used without diffuser, this yields a much greater intensity for short slit/point source observations.
- The fibre-optic mixer reduces the intensity of the calibration lamps by a factor of 6; if an observer only needs to use one calibration lamp, and it is important to get the maximum intensity, it is possible to replace the mixer by a one-to-one lightguide, which efficiently relays the light from one lamp onto the diffuser. With this option, the obsever must decide whether to select a flatfield *OR* wavelength calibration source; both cannot be selected!

Just before the diffuser are two filter wheels, for colour and neutral–density filtering of the calibration light. The filters contained within these wheels are summarised in Tabs. 2.10 and 2.11. Transmission curves are shown in Figs. A.4 and A.5. [2]

5.1.8 Details of the 1994 upgrades to the UES A&G unit

During the summer of 1994 it is expected that an improved A&G unit will be installed and commissioned at UES. The features that will be offered by the new unit are detailed below:

REQUIREMENTS FOR UES FIBRES ENHANCEMENT

1. Only 2 fibres bundles will be required, one for slit viewing and one for off-axis guiding. It will be possible to view the fields from both fibres on the CCD simultaneously.
2. The enhanced optical/fibre system will work with the existing autoguider head.

Notes:

[2] the general philosophy of filter use is to use main-beam filters to:

- reject unwanted wavelengths (far red for CCD, blue for the IPCS, all except one order for long-slit work).
- match object flux to detector in use so as to avoid saturation (mainly a point of consideration with IPCS-II).

Having determined the correct main-beam filter for the science exposure, these must also be used for calibration exposures.

3. Each fibre will have a field of view of 20×20 arcsecs
4. Image scale on CCD will be in range 0.15 to 0.2 arcsec/pixel
5. Overall improvement in sensitivity of off-axis channel will be at least a factor of 20, with a factor of about 10 or possibly more from the fibre/optical components, and a factor of 2 from the autoguider CCD. This should take the limiting magnitude to about 17th in V.
6. Overall improvement in sensitivity of slit-view channel to a similar limiting magnitude (ie. to about 17th magnitude including the CCD improvement).
7. Wavelength coverage will be 400-700 nm.
8. It will be possible to adjust the focus for each fibre

Additional related enhancements that will be provided are:

- The range of ND filters will be re-specified.
- The TCS software will be modified to cope with differential refraction
- A thinned CCD will be provided in the autoguider head. This will almost certainly be an EEV device, to minimise the changes required to the existing autoguider system.
- It will be possible to guide using either fibre
- The autoguider software will allow read out and display of both windows, whilst guiding on either.

Chapter 6

Instrument performance

6.1 Stability

The instrument is extremely stable. Over a 12 hour period, with the telescope slewing and tracking, no line-shifts greater than 5 microns were measured.

6.2 Repeatability

6.3 Scattered light

Stray-light, measured between interference orders and on stars with black absorption lines, is at a very low level, of about 2-3 per cent.

6.4 Ghosting

6.5 Throughput

The efficiency of the spectrograph, excluding the telescope, image derotator and detector, is expected to be about 36 per cent. This assumes an efficiency for the cross-disperser of 86 per cent, for the echelle of 60 per cent, and for the camera of about 70 per cent.

The total throughput of the spectrograph also depends on the slit width. A wide slit will let in more light, but will degrade the wavelength resolution, and the optimum tradeoff between these considerations will vary from observation to observation.

For a one arcsecond slit, the limiting magnitude of the instrument, defined as the magnitude of a star from which 100 counts per resolution element is obtained at a wavelength of 5500 Åwith an exposure time of 10,000 seconds, is estimated to be about m_v=17.5.

The throughput of UES+WHT is in fact measured to be very similar to that of UCLES+AAT. The extra light collected by the WHT is lost in the derotation optics. In general we therefore expect UES+WHT to go slightly deeper than UCLES+AAT, due to the better seeing conditions on La Palma.

Chapter 7

Observing with UES

7.1 Starting up

7.1.1 Instrument control microprocessor

The UES 4MS microprocessor control system should normally have been left running. If for any reason you need to reinitialise or reload the system, press the red reset button on the 4MS. (This is located behind the top panel of the 4MS computer rack, you may need to unscrew the cover plate to access the red button.) This will load the system from Eprom.

Having loaded the system, you will need to initialise all mechanisms. You can do this from the instrument control computer by typing `UES_INIT ALL` at the ICL prompt. This takes a long time (about 15 minutes), so don't reinitialise the 4MS unless you have to.

7.1.2 Instrument control computer

To start up the instrument control computer log on to the instrument control VAXstation (LPVS2 as of 1994) as either OBSERVER or OBSTEST (passwords WHT_OBSERVER and WHT_OBSTEST respectively), depending on whether you're running the standard or the test system; check the the whiteboard in the WHT control room to see which account you should run up. Then set host to LPVF and login again with the same username and password. You are now logged into the instrument control computer.

To start the observing system simply type ICL. You will be prompted for your initials and PATT/CAT reference number, and then asked to select from a menu the instrument combination you want to use. This will be either UES+CCD or UES+IPCS depending on which detector is mounted.

If using a CCD, the correct detector must have been defined in [OBSERVER.CONFIG]WHT_DETECTORS.DAT (or [OBSTEST.CONFIG]WHT_DETECTORS.DAT if logged on under OBSTEST). The correct values will have been entered by the Duty Technician or Support Astronomer for you.

7.1.3 Instrument hardware

Once the control system has been started, check that the lightpath through the instrument is clear:

- The darkslide should be opened at the start of the night. This is normally done by the telescope operator. It should be closed again at the end of the night, to prevent dust entering the instrument.
- Check on the mimic that the interface cover is off — this is a manually operated safety shutter blocking light to the detector. If it is not, it will have to be moved manually; the support astronomer should normally do this.
- The camera shutter should be open. If the 4MS has been reset it will be closed, in which case type `UCAMSHUT OPEN` at the ICL prompt.

7.1.4 Telescope Control Computer

Starting up the instrument control computer should automatically start up the Telescope Control Computer. The following commands should then be issued, normally by the telescope operator:

TCS>	`UES DEROT`	Select UES focal station with derotator
TCS>	`INSTRUMENT UES`	Define correct instrument offsets
TCS>	`AGSELECT UESCOARSE`	Define autoguider in use
TCS>	`ENTER APERTURE 1 -0.5 -3.4`	Define apoff onto slit
TCS>	`ENTER APERTURE 2 -76.5 -5.4`	Define apoff for TV acquisition

7.1.5 Acquisition TV

The UES TV system should be switched on as described in the WHT Users manual. The H scan switch should be up and the V scan switch down.

Mark the TV pixel (148,217), since this will be used as the reference point for object acquisition.

7.1.6 Autoguider

The autoguider should be powered up as described in the WHT users manual. Once it has booted, type UES LOAD, and then START-UP.

7.1.7 Input of user source catalogue

At this stage it is usual to input the observer's target source catalogue. This can be prepared before hand on one of the VAX/VMS machines and then transferred across to the TCS.

The input file should be a simple ASCII file containing details of one source per line, of the format:

`<source_name> <right_ascension> <declination> <equinox>`

an example might be:

`HD123456 12 34 56.789 11 22 33.44 B1950`

The file can then be transferred to the TCS with the TCS command INCLUDE `<catalogue_name>`. An example might be:

TCS> `INCLUDE LPVE::DISK$USER1:[GUEST02.CAT]TARGETS` where the file TARGETS.CAT will be transferred to the TCS.

Full details can be found for these commands in the WHT Users' Manual (1994).

7.2 System checks

Normally the detector should have been mounted so that with the wideband collimator and no focal modifier lens, the collimator focus is close to the middle of range. If there is time it is sensible to use a Hartmann test to check the focus of the spectrograph before the start of each nights observing. How to do this is described in section 8.4.

The performance of UES is constantly monitored. Various quality control procedures are carried out at the start of each run. The Support Astronomer will ensure that the QUALITY CONTROL procedures detailed in the UES QUALITY CONTROL folder are carried out.

*** Include here sections from the quality control folder. ***

7.3 Starting observing

7.3.1 Telescope and autoguider focus

It is necessary to check the focus of the telescope at the start of the night. The various means of viewing the field in order to do this are described in section 5; there are three fibre light guides, one in a fixed position viewing the central part of the slit, and two which can be moved to view stellar images in any part of the field directly. In addition, an ISEC TV can be used to view most of the field reflected off the slitjaws, but at a rather coarse scale.

The focus of the ISEC TV and the slitviewer probe can only be adjusted manually, and should not need to be checked. However, the focus of the coarse and fine autoguider probes can be changed under computer control, and should be checked.

The first thing to do is focus the telescope. The ISEC TV provides too coarse a scale for this to be done accurately, and so it will be necessary to do this on one of the three guide probes. The focus of the telescope and the focus of the offset guide probes are interdependent, so until the focus of the offset guide probes has been determined it will be necessary to focus on the slitviewing fibre.

To focus on the slitviewing fibre, acquire a star onto the slit, and start the autoguider continuously reading out the slitviewer CCD window (section 7.4.1). Close the slit right down and move the dekker out of the way (type `USLITWIDTH 20 MICRON` and `USLITLEN 10 ARCSEC` at the ICL prompt). Use the TCS handset to move the star slightly off the slit, and then focus the he focus of the offset guide probes has been determined it will be necessary to focus on the slitviewing fibre.

To focus on the slitviewing fibre, acquire a star onto the slit, and start the autoguider continuously reading out the slitviewer CCD window (section 7.4.1). Close the slit right down and move the dekker out of the way (type `USLITWIDTH 20 MICRON` and `USLITLEN 10 ARCSEC` at the ICL prompt). Use the TCS handset to move the star slightly off the slit, and then focus the telescope. This will be difficult, since the field viewed by this fibre is extremely small !

A more reliable focus can be obtained by acquiring a bright star and taking quick exposures at a number of telescope positions. The FWHM of the stellar spectrum can be measured using either the DMS or IRAF on the SPARCstation. By plotting FWHM against telescope focus, the best focus can be determined.

It should be noted that the telescope focus is expected to be different to that obtained at Cass. It will also be different with and without the derotation optics mounted. Inserting the derotation optics requires the telescope to be refocussed by moving the secondary mirror downwards by 3.82 mm (see La Palma Technical Note 9). See the telescope log or the quick reference section of this manual for previously used focus settings.

Once the telescope is focussed, focus the autoguider by acquiring a star onto the coarse guide probe, and starting the autoguider continuously reading out the coarse guide probe CCD window (section 7.4.1). Adjust the autoguider focus using the `UAGFOC` command. The autoguider filters all have the same thickness (including the clear position, which is actually fused silica), so the focus is independent of which filter is selected.

Once the autoguider focus has been checked, at the start of an observing run, it should be fairly stable from night to night. It should then be possible to check the telescope focus each night by acquiring a star onto the coarse guide probe, and continuously reading out the CCD window whilst adjusting the focus using the TCS handset.

N.B. Remember—the WHT focus (and consequently the autoguider focus) will need to be adjusted to compensate for any change in the thickness of main-beam filters used (see sec. 5.1.3).

7.3.2 CALIBRATE procedure

Before starting to observe astronomical targets, the CALIBRATE procedure should be carried out. It is extremely important not to skip this, since the efficiency of object acquisition with UES depends critically on the telescope pointing, much more so than with the Cassegrain instruments.

The CALIBRATE procedure is described in general terms in the telescope manual. The procedure with UES differs from carrried out at Cassegrain, in that instead of centring stars on the field-viewing TV, stars should be centred on the coarse guide probe, with the guide probe positioned at the rotator centre with the ICL command `UPROBEVIEW`. The autoguider window corresponding to the coarse guide probe should be read out continuously, whilst each star is centred using the TCS handset.

The commands to do this are as follows. Commands with the ICL prompt are issued from the system computer, commands with the TCS prompt are issued from the Telescope Control System, and commands with the A&G prompt are issued from autoguider VME system.

A&G>	1 READOUT-FIBRE	Start continuous readout of coarse probe
ICL>	UPROBEVIEW	More guide probe to rotator centre, move AG mirror
TCS>	CALIBRATE	Start calibrate procedure
	-	
	-	Centre all the stars using TCS handset
	-	
A&G>	STOP-TRACK	Stop AG continuous readout

7.4 Acquisition and guiding

The Nasymth A&G provides facilities for object acquisition, and for guiding off both offset guide stars and the slit image. These facilities are described in section 5, and summarised in Tab. 7.1. Sections 7.4.1 and 7.4.2 describe how to carry out acquisition and guiding, whilst section 7.4.3 describes the limiting magnitude of the system.

Table 7.1: Options for field viewing and guiding

Option	Field (arcsec)	Scale (arcsec/pix)	Notes
TV slitviewer	≈300	1.4 in X	Centre of slit not visible
		0.8 in Y	TV not useable during an exposure
Coarse guide probe	13	0.27	Not UV (< 3500Å transmitting)
Fine guide probe	4.4	0.13	UV transmitting
Slitviewing probe	4.4	0.13	UV transmitting

7.4.1 Object acquisition

The three principal field viewing options described above (TV slitviewer, coarse guide probe, slitviewing probe) provide a sequence of improving plate scale at the cost of decreasing field of view. For objects bright enough to be visible with all three options, the most general acquisition sequence is to use the TV slitviewer for field verification and coarse centering of the target, then to switch to the coarse guideprobe to centre up more accurately, and finally to switch to the slitviewing probe to centre up on the slit.

Experience has shown that exposures are often not sufficiently well centred on the slit. An automatic procedure using the coarse guide probe to accurately centre on the slit as a last step in the centering process is under development—check with your support astronomer for status.

In practice, as long as the telescope is performing properly, and the target coordinates are accurate, it is not usually necessary to carry out first step in this sequence. It is possible to acquire a target directly onto the coarse guide probe. The TV is therefore only needed in cases where uncertainty over the field exists, due perhaps to inaccurate coordinates.

The majority of UES observations will require the sky PA of the spectrograph slit to be set to the parallactic angle. Two options exist here, either to have the rotator track the parallactic angle during the obervation, or to set the rotator (static) at or near the parallactic angle at the start of the observation. Ask the telescope operator to do this before starting the acquisition process.

The three field-viewing options view different parts of the telescope focal plane, and it is therefore necessary to define three apertures in the focal plane. It is then straightforward to apply an aperture offset to move between these three apertures. Table 7.2 summarises the parameters of these three apertures.

The detailed procedure is as follows. Commands with the ICL prompt are issued from the system computer, commands with the TCS prompt are issued from the Telescope Control System, and commands with the AG prompt are issued from autoguider VME system.

Table 7.2: Aperture offsets for UES acquisition

Aperture no	X offset (arcsec)	Y offset (arcsec)	Function
0	0	0	For viewing rotator centre using coarse probe at (35540,41200)
1	-0.5	-3.4	For viewing centre of slitjaws using slitviewing probe
2	-76.5	-5.4	For viewing slitjaws using unobstructed part of TV field TV coordinates are (148,217)

TCS>	`GOCAT NGC4151`	Move telescope to target
TCS>	`APER 2`	Apply aperture offset to unobstructed part of TV field
ICL>	`UTVVIEW`	Configure A&G for TV viewing
		Use TCS handset to centre object on TV pixel (148,217)
TCS>	`APER 0`	Apply aperture offset to rotator centre
ICL>	`UENDTVVIEW`	Reset slit angle and dekker
ICL>	`UPROBEVIEW`	Move guide probe to rotator centre, move AG mirror
A&G>	`SELECT COARSE`	Select coarse probe
A&G>	`ACQUIRE ON`	Start continuous readout of coarse probe
		Use TCS handset to centre object
TCS>	APER 1	Apply aperture offset to slit
A&G>	`AQUIRE OFF`	Stop continuous readout of coarse probe
A&G>	`SELECT FINE`	Select fine probe
A&G>	`ACQUIRE ON`	Start continuous readout of slitviewing probe
		Use TCS handset to centre object

Note that in order to use the TV viewer, the `UTVVIEW` procedure sets the slitangle to zero and moves the dekker out of the beam. Before you start observing again the slitangle and the slitlength must be reset to their previous values with the command `UENDTVVIEW`.

For objects too faint to be visible on the field-viewing probes, the procedure summarised above should be followed on a nearby bright star, and a blind offset then used to centre the target on the slit.

7.4.2 Guiding

7.4.2.1 Autoguiding using offset guide stars — found using GSS

The principal difference between offset guiding at Cassegrain and with UES is the much smaller field visible through the Nasymth A&G guide probes. It is essential to have some means of predicting where to put the guide probes in order to pick up a guide star. The Guide Star Server is now available and provides a useful means of quickly locating guide stars.

The normal procedure for offset guiding is to use the Guide Star Server (GSS) to locate a guide star. Documention for the GSS is located in the WHT Control Room. The GSS is presently run on the ING VAX/VMS cluster to which you should have a GUEST account. To set up the symbols needed to run the GSS, execute the command procedure:

```
@DISK$USER3:[GSS]GSS_INIT
```

Then type `GSS` to start the software, which will respond with a GSS> prompt. A simple GSS session follows:

$ GSS		
GSS>	CONFIG WHT UESCOARSE	Configure for UES
GSS>	ROTATOR *n*	Set rotator to position *n*
GSS>	SEARCH 12 34 56.23 30 00 02 J2000	Coords of science object
GGS>	EXIT	End session
$ TYPE OUTPUT.GS		

This finds upto the 10 brightest guide stars available for the WHT UES focus at the specified position for rotator position angle n (where the rotator position angle is the rotator position on the sky—often set to the parallactic angle for observations of point sources). The position and probe coordinates for the guide star are given in OUTPUT.GS, which is the default output file name. . the required slitlength. The larger the field required at the slit, the smaller the field available for finding guide stars; this is a critical tradeoff to consider, particularly out of the galactic plane, where the number of guide stars available is small. Table 5.1 summarises the unvignetted and partially vignetted field provided by each of the options. Figure 3.5 shows plots of the vignetting along the slit.

Having got light from the guide star down the guide probe, the procedure to follow is almost identical to that for guiding at Cass. Take a test exposure to locate potential guide stars, start generating guide errors, and tell the telescope to start correcting for the guide errors. It is possible to vary the autoguider integration time, and also to select from a range of autoguider filters.

The detailed procedure is as follows. This example assumes observations using a short slit, and autoguiding using the coarse guide probe. Commands with the ICL prompt are issued from the system computer, and commands with the TCS prompt are issued from the Telescope Control System, whilst commands with the A&G promopt are given at the autoguider terminal.

A&G>	UES	Select UES focal station for autoguider
		Should be selected at start of each night - once only
TCS>	AGSELECT UESCOARSE	Tell TCS which guide probe is being used
		(Relevant options are UESCOARSE or UESFINE)
ICL>	UMIRROR SHORTSLIT	Select appropriate position of autoguider mirror
		(Relevant options are POINTSOURCE, SHORTSLIT, LONGSLIT)
ICL>	UAGXY COARSE x y	Drive coarse guide probe to pick up guide star
A&G>	SELECT COARSE	Select coarse fibre
A&G>	ACQUIRE ON	Turn on continous acquistion
A&G>	ACQINT *n*	Set integration time (*n*)of test exposure in msecs
A&G>	ADD SLIT	Should see target on slit, guide star on coarse probe
		At this stage tweak the telescope position to ensure that the target is on the slit
		The coarse probe may need to be moved slightly to re-centre the guide star
A&G>	ACQUIRE OFF	Turn off continous acquistion
A&G>	SELECT COARSE	Select coarse fibre for guiding
A&G>	ADD SLIT	Show slit as well
A&G>	GUIDE ON	Close loop and start generating guiding errors
A&G>	GUIINT *n*	Adjust guide time - typically 1000—2000 msecs
TCS>	AUTOGUIDE ON	Start telescope guiding

Before moving to a different target , type:

TCS>	AUTOGUIDE OFF	Stop telescope guiding
A&G>	GUIDE OFF	Stop generating guiding errors

Note that it is not necessary to use the PROBE command to tell the TCS the guide probe coordinates. This is necessary at Cassegrain because the autoguider orientation is a function of the probe coordinates;

this is not the case at Nasymth. Further the A&G FIELD command is not needed at UES.

Ful details on the use of the autoguider can be found in the WHT Autoguider User Manual.

It is planned to eventually implement all commands presently issued at the A&G console at the ICL console.

7.4.2.2 Autoguiding using offset guide stars—found using TV

In cases where there is no suitable guide star found when using the Guide Star Server, it is possible, before starting an exposure, to use the TV slitviewer to search for possible guide stars in the outer part of the field. The coordinates of the guide star can then be read using the TV cursor, and either the coarse or fine guide probe driven to the correct position to view that guide star.

The following points should be noted:

- Using the TV viewer to select guide stars requires the slit angle to be set to zero degrees and the dekker to be moved out of the beam. Having selected the guide star, it is important to remember to set the slitangle and slitlength back to that required for the observation with the command **UENDTVVIEW**.
- The relationship between guide probe coordinates and TV coordinates may change, for example if the TV is exchanged. If this happens, the relationship must be recalibrated as discussed in section 8.1 before the procedure described here can be expected to work.

The detailed procedure is as follows. This example assumes observations using a short slit, and autoguiding using the coarse guide probe. Commands with the ICL prompt are issued from the system computer, commands with the TCS prompt are issued from the Telescope Control System, and commands with the A&G prompt are entered at the A&G terminal.

TCS>	`AGSELECT UESCOARSE`	Tell TCS which guide probe is being used
		(Relevant options are UESCOARSE or UESFINE)
ICL>	`UTVVIEW`	Setup for slit viewing of field
		Determine TV pixel coordinates (x,y) of guide star
ICL>	`UENDTVVIEW`	Reset slitangle and dekker to values required for
ICL>	`UMIRROR SHORTSLIT`	Select appropriate position of autoguider mirror
		(Relevant options are POINTSOURCE, SHORTSLIT, LONGSLIT)
ICL>	`UGDXY COARSE x y`	Drive coarse guide probe to pick up guide star
A&G>	`SELECT COARSE`	Select coarse fibre
A&G>	`ACQUIRE ON`	Turn on continous acquistion
A&G>	`ACQINT` *n*	Set integration time (*n*) of test exposure in msecs
A&G>	`ADD SLIT`	Should see target on slit, guide star on coarse probe
A&G>	`ACQUIRE OFF`	Turn off continous acquistion
A&G>	`SELECT COARSE`	Select coarse fibre for guiding
A&G>	`ADD SLIT`	Show slit as well
A&G>	`GUIDE ON`	Close loop and start generating guiding errors
TCS>	`AUTOGUIDE ON`	Start telescope guiding

Before moving to a different target, type:

TCS>	AUTOGUIDE OFF	Stop telescope guiding
A&G>	GUIDE OFF	Stop generating guiding errors

7.4.2.3 Autoguiding on the slit image

If no offset guide stars are available, and the object being observed is bright enough to be visible on the slit using the slitviewing probe, then it is possible to autoguide on this image. The procedure is very similar to that described above for offset guiding. It is made difficult in practice by the small field of view available.

The detailed procedure is as follows. Commands with the ICL prompt are issued from the system computer, and commands with the TCS prompt are issued from the Telescope Control System.

ICL>	UMIRROR SHORTSLIT	Make full field visible at slit
TCS>	AGSELECT UESSLIT	Tell TCS which guide probe is being used
A&G>	SELECT COARSE	Setlect coarse fibre
A&G>	ACQUIRE ON	
		Once the target object is found, tweak the telescope to centre it on the coarse fibre
A&G>	ACQUIRE OFF	
A&G>	SELECT SLIT	now centre object on slit
A&G>	GUIDE ON	start generating guiding errors
		Use GUIINT *n* to change guiding time
TCS>	AUTOGUIDE ON	Start telescope guiding

Before moving to a different target, type:

TCS>	AUTOGUIDE OFF	Stop telescope guiding
A&G>	GUIDE OFF	Stop generating guiding errors

7.4.2.4 Manual guiding off the slit image

It is possible that the object is visible on the slit, but is not suitable for autoguiding. For example, the object may be too extended, too faint for the software centroiding, or the slit may be too wide for the software centroiding algorithm. In such a case it may be possible to guide manually on the slit image.

The procedure is to set the CCD autoguider continuously reading out the window corresponding to the slitviewing probe, and then use the TCS handset to guide.

The commands to do this are as follows.Commands with the ICL prompt are issued from the system computer, commands with the A&G prompt are issued from the autoguider terminal.

ICL>	`UMIRROR SHORTSLIT`	Make field visible at slit (Possible options are
POINTSOURCE, SHORTSLIT, LONGSLIT, CLEAR)		
A&G>	`SELECT SLIT`	Select slit for guiding
A&G>	`AQUIRE ON`	Start continuous readout of slitviewing probe
		Now guide manually using TCS handset
		Adjust acquire time with `ACQINT` *n* msecs if needed
A&G>	`ACQUIRE OFF`	Stop continuous readout of slitviewing probe

7.4.3 Limiting magnitudes for acquisition and guiding

The limiting magnitude for the coarse guide probe is at about m_v=14.5. The limiting magnitude for the slitviewing probe is at about m_v=15.5

7.5 Spectrograph configuration

As discussed in section 3.3, it is necessary to specify the following parameters in order to configure the spectrograph to take data:

- Choice of echelle grating, central wavelength and order number.
- Slitwidth and length

The commands `UCENWAVE31` and `UCENWAVE79` configure the spectrograph for observations with the 31.6 and 79.0 lines/mm echelles respectively. The central wavelength must be specified as the first parameter. The order number is an optional second parameter; if it is not specified the order will be selected which puts the central wavelength closest to the peak of the blaze function, as shown in Tabs. 3.2 and 3.3.

The required echelle grating will be moved into the beam, and the echelle theta and gamma angles, the slit angle and the prism position for the requested wavelength selected. The optimum collimator will be selected (wideband or UV); if the collimator is exchanged a predetermined focus offset will be applied.

Set the slitwidth and slitlength using the `USLITLEN` and `USLITWIDTH` commands. The values can be given explicitly; in the case of the slitlength it is possible to get the control system to select the slitlength automatically by typing USLITLEN AUTO (the slitlength is set to the longest possible value consistent with there being adequate interorder spacing).

Some examples follow:

ICL>	UCENWAVE79 5000	Use 79.0 echelle at 5000 Å (order 45 automatically selected)
ICL>	USLITLEN 12 ARCSEC	Set slitlength to 12 arcsec
ICL>	USLITWIDTH 1 ARCSEC	Set slitwidth to 1 arcsec
ICL>	UCENWAVE31 3269	Use 31 echelle at 3269 Å (order 174 automatically selected)
ICL>	USLITLEN AUTO	Set slitlength automatically (will be set to ?? ARCSEC)
ICL>	USLITWIDTH 1 ARCSEC	Set slitwidth to 1 arcsec
ICL>	UCENWAVE31 6000 95	Use 31 echelle at 6000 Å (order 95 automatically selected)
ICL>	USLITLEN AUTO	Set slitlength automatically
ICL>	USLITWIDTH 1 ARCSEC	Set slitwidth to 1 arcsec

7.6 Data acquisition—Notes for the observer

7.6.1 Notes to the observer

The reduction of spectra collected using the modern CCD and IPCS detectors often require complex procedures in order to ensure that the best possible results are obtained. In many cases, the dataset which the observer brings back from the Observatory is incomplete in the sense that some of the data required for an ideal reuction is missing. It is therefore vital for the observer to ensure that equal effort is paid to obtaining a comprehensive set of calibration frames, to that which was expended on the 'Object' frames. Different types of object will produce different requirements in terms of calibration and the following are merely guidelines.

7.6.1.1 Orientation of spectra

The detectors are frequently aligned on the Spectograph such that the central order falls (mainly) parallel to the detector rows or columns. The orders themselves however, are often not parallel to each other. The algorithms used for tracing orders assume the orders run approximately in the horizontal direction. It is therefore necessary to rotate any column-parallel frames before reduction (through 90 degrees).

The package is very flexible as to the exact order orientation and highly sloped and severly distorted orders can usually be extracted without difficulty *provided that a tracing frame of sufficient quality is provided.* This will generally in the form of a bright star exposure, or a template trace frame such as an exposure of a continuum lamp (with a narrow dekker preferably).

If the target object under study is sufficiently bright, then the object frame itself can of course be used as the trace template frame. The package is capable of tracing very poor object frames, *but* with the result that the modelled order positions will be less well determined, impacting on all subsequent phases of a reduction. The user is therefore strongly encouraged to provide the best order tracing template possible.

7.6.1.2 CCD bias frames

A bias current is routinely applied to CCD detectors to ensure that they are operating in as near as possible linear manner. This current has the effect that a non-zero count is recorded in all pixels. The observer should ensure that a number of 'bias frames' are obtained to adequately estimate the effect. The average of the bias frames should be taken, and the result subtracted from all other frames before using them in a reduction. Failure to account for the bias may have a detrimentel effect on the S/N in the final spectrum.

7.6.1.3 CCD overscan

CCD frames typically include a nunber of rows/columns not exposed to the light. The pixels in these rows often contain high counts and can affect some of the automatic reduction procedures. It is prudent to clip off these rows/columns before reduction proceeds. They will be the same for all frames and can thus be removed using a simple looping command procedure.

7.6.1.4 Dark count

Dark frames are essential for some applications. They are advisable when using on-chip binning. For CCDs, the dark current may also be high if it has been exposed to too much light, or if power has been interrupted to a cold chip. A number of long exposure (30 to 60 mins) dark frames should be combined using a median filter, and the result scaled according to the object frame exposure time. This frame may then be subtracted from the object frame before reduction begins. If you wish to ensure that the error properties are accounted for then the dark frame should be copied into the object frame variance array.

Again for CCDs only, a further advantage of collecting long exposure dark frames is the option of deriving an independent estimate of the rate of cosmic ray events as a function of their intensity. This can provide a useful comparison with long exposure object frames and a check on how reliably cosmic ray removal has been.

7.6.1.5 Flat fielding

A bright quartz lamp should be used with a dekker size a few steps larger than that used for the object observations, but order overlapping should of course be avoided. It is important to ensure that all orders are as bright as possible. It may be necessary to use different flat field exposures to obtain good frames when observing in a spectral region where the quartz lamp intensity or detector efficiency changes rapidly. Each flat field frame should be constructed by calculating the median of a large number of runs where possible. If you wish to include the errors on the flat field then they should be placed in the flat field variance array. If no variance estimates are provided then the package will assume root N statistics apply. The package can utilise different flat field frames for different orders if required.

7.6.1.6 CCD gain

Many of the algorithms used assume that photon counting statistics apply. However, it is unnecessary to correct raw frames since the conversion factor (ADUs/photon) is prompted for when required.

7.6.1.7 Arc frames

In general arc frames should be obtained to bracket each object exposure in time, allowing us to check that no shift has occured during the exposure. An advantage of using a single frame (possibly generated by co-adding the before and after arc frames) is that this allows the resolution of the final spectrum to be easily investigated. This is because the arc spectrum is always extracted in an identical manner to that of the object; using the first (and in this case only) supplied arc frame. As with the flat field frame it may also be advantageous to take multiple arc frames, each exposed correctly to ensure high S/N in particular orders. The package is capable of using a different arc frame for each order if required.

7.7 Data acquisition with the CCD

7.7.1 Setting up and acquiring data

The data acquisition system is described in detail in the Data Acquisition System (DAS/CCD) users manual, and hence a full description will not be repeated here.

To make the system ready to take data, the correct CCD format must be set up. Type SETUP UES at the ICL prompt. You will be prompted for the size in x and y of the image, the system will suggest default values. (N.B. The default sizes are also listed on the Whiteboard in the WHT Control Room. At present (Jan 1994) the two main CCD's have sizes: EEV3, EEV6: 1280×1180; TEK1, TEK2: 1124×1124.)

Unless you have been briefed to use an unusual CCD format, you should accept the default values; remember that you can later cut down the size of the images by windowing and binning.

Select the readout mode of the CCD using the `TURBO, SPEEDY, SLOUCH` or `SLOW` commands, for example:

```
ICL> SPEEDY UES
```

(N.B. In addition to the above mentioned readout modes there is a further mode giving the fastest readout. This mode is called `NONASTRO` and is meant for setup purposes only due to the high readout noise. A full description of the CCD readout modes can be found in the CCD quality control folder kept in the WHT Control Room.)

To make an observation use the RUN command, for example:

```
ICL> RUN UES 100 "NGC1068"
```

This requests an observation of 100 seconds, with the observation title NGC1068. The system will prepare the detector, expose the detector for the requested time, collect the image data in the DMS, collect header information describing the observation, and write the image and headers to a disk file on the system computer. The system will have allocated a run number to the run and will have sent you a message stating the number. The run number is also to be seen on the MIMIC display.

The datafile will have been created in the directory pointed to by the logical name RUN_FILES. All the datafiles from a given night's observing appear in the same directory on disk. Type the command DIR at the ICL prompt if you want to check the contents of this directory. The naming convention for files is such that run number 94151 would be written to a file named R0094151.SDF. (Hence in the near future: run number 10010 will be written as R010010.SDF).

7.7.2 Quick-look and setup

If you want to take a quick look at data, displaying it on the DMS or SPARCstation, but not collecting header information or copying the data to disk on the system computer, do a glance exposure:

```
ICL> GLANCE UES  5
```

In this example, a 5-second exposure is made and the data appears in the DMS. The data can then be inspected before proceeding further.

If you decide you want to keep this data on the system computer after all, type

```
ICL> KEEP UES [TITLE="<title>"]
```

This command will assign a run number, collect headers and write the data to a disk file in RUN_FILES a for a normal run. Note that if you have changed the instrumental setup between taking the glance exposure and saving it the headers will be incorrect.

To make an observation that you do not intend to retain, but which you want to save to disk on the system computer, use the `WINK` command.

```
ICL> WINK UES 1 <observation type> <exposure time> [TITLE="<title>"]
```

causes the data (image plus headers) to be written to a 'scratch file' S1.SDF in the directory SCRATCH_FILES. Scratch files have headers but aren't allocated run numbers; they are temporary files that should not be exported from LPO.

Any number of such scratch files may be created (subject to disk-space constraints) by substituting another file number for the 1 in the command. If you make a scratch exposure into an existing scratch file, the new data over-writes the old.

SCRATCH_FILES is initially the same directory as RUN_FILES but this can be changed by redefining the logical name *at job level.* [1]

An example definition would be:

```
$ DEFINE/JOB SCRATCH_FILES <directory path>
```

If you later find that you want to keep a scratch file, you can convert it to a proper run using the `PROMOTE` command.

```
ICL> PROMOTE 1
```

causes scratch file 1 to be allocated a run number and moved to RUN_FILES.

7.7.3 Windowing and binning CCD data

To window a CCD, type the following.

```
ICL> WINDOW UES
```

You will then be prompted for the number of windows to be set up, and the start position and size of each one. Setting up more than one window per channel may be counter-productive in terms of the final image size: discuss this with your support astronomer.

(N.B. To date (Jan 1994) the active areas of the CCD's are: EEV—x=?–?, y=?–?; TEK—x=?–?, y=?–?. This information is also to be found in the CCD Quality Control Folder, kept in the WHT Control Room.)

To bin the CCD, use commands such as

```
ICL>  BIN UES 2 2
ICL>  BIN UES 2 1
```

where the parameters give the binning factors in x and y.

You can temporarily disable windowing, return to reading out the whole CCD, and then re-enable the windows:

```
ICL> DISABLE_WINDOWS UES
ICL> RUN UES 10
ICL> ENABLE_WINDOWS UES
```

Note that enabling and disabling the windows does not change the binning. Binning factors are reset to (1,1) and windows are disabled when a channel is set up.

Notes:

[1] If you don't understand this fully, don't try it.

7.7.4 Stopping and starting CCD exposures

If you need to pause and then restart a CCD exposure, do so using the following commands:

```
   ICL> PAUSE UES
   ICL> CONTINUE UES
```

You can change the exposure time of a run in progress by issuing the following command:

```
ICL> NEWTIME UES <time in secs>
```

If you need either to abort a CCD exposure or stop it before the pre-set exposure time has elapsed, you can either set a new exposure time as above or use the following commands:

```
   ICL> ABORT UES
   ICL> FINISH UES
```

Remember that the `ABORT` command throws the data away!

7.7.5 Multiple sequential exposures

For each of the single exposure commands defined above, a multiple exposure version exists.

```
ICL> MULTARC UES <number of runs> <time in secs>
```

For example, use the following command to take ten 60 second science exposures:

```
   ICL>  MULTRUN UES 10 60
```

7.8 Data acquisition with the IPCS-II

Full details of the IPCS-II detector are given in the IPCS-II User Guide (Dicks et al 1989). Hence only a brief summary of its use will be given here.

Saturation of the IPCS-II detector will destroy the S20 photcathode. Hence caution should be used when working with this detector system in ensuring that strong light NEVER illuminates the detector.

7.8.1 Setting up and aquiring data

7.8.2 Quick-look and setup

7.8.3 Stopping and starting IPCS-II exposures

7.8.4 Recovering from an 'overillumination' situation

7.9 Calibration

To take a calibration frame you will need to move the A&G mirror so that light from the calibration unit is directed into the spectrograph, and then turn on one of the comparison lamps. You may wish to select one of the filters in the calibration unit filter wheels. A typical command sequence might be as follows:

ICL>	UMIRROR ULAMPS	Move mirror
ICL>	ULAMPS THAR	Turn on ThAr lamp
ICL>	UCOMPFILTC RG780	Select colour filter
ICL>	UCOMPFILTND ND3.0	Select ND filter
ICL>	ARC UES 30 "THAR ARC 10S"	Take arc exposure of 30s

If you require a very uniform illumination, you should use one of the diffusers in the calibration unit. Ask your support astronomer to select this. This should not normally be necessary, and it is normally much more efficient to observe without the diffuser.

To take a calibration frame, use the most appropriate of the following commands: `FLAT, SKY, ARC, MAP, DARK, BIAS` and `FLASH`. The first four of these commands (`FLAT, SKY, ARC, MAP`) differ only from the RUN command discussed above in that a different observation type is written to the header, in order that data-reduction software can recognise calibration exposures and process them accordingly. The `DARK` command carries out an exposure of the specified length, but without opening the CCD shutter, whilst the `BIAS` and `PREFLASH` commands carry out zero length exposures.

It is possible to take multiple exposures using one of the following commands: `MULTFLAT, MULTSKY, MULTARC, MULTMAP, MULTDARK, MULTBIAS` and `MULTFLASH`.

7.9.1 Atlas of the Thorium-Argon lamp

As an aid to the identification of the lines in the Th-Ar arc spectra, RGO has produced an atlas giving the identifications for the Thorium and Argon lines in the spectrum of the hollow-cathode comparison lamps used for wavelength calibration of UES. (La Palma Tech. Note No. 91, 1993)

This publication can be found in the control room of the WHT. Copies can also be obtained from Bill Martin at RGO (wlm@mail.ast.cam.ac.uk).

7.10 Common problems

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7.10.1 Spectrograph not configured properly

If you get an error message saying that the spectrograph has not configured to a specified central wavelength, the most likely cause is that one of the echelle mechanisms has not reached the demanded position. In the first instance initialise the mechanism that shows *red* on the mimic with the command:

```
ICL> UES_INIT <mechanism>
```

Then reissue the `CENWAVE31` (or `CENWAVE79`) command. If any of the mechanisms still fail to reach their demanded positions then call the Duty Tech or Support Astronomer to investigate the problem further.

7.10.2 No calibration light reaching the detector

Check the following:

- The comparison lamps should be on, *and* the comparison lamp shutters open. It is possible to check that the comparison lamps are drawing current by inspecting the meters in the NAG electronics rack on the Nasymth platform.
- Check the mimic to see which diffuser is in the beam. At a wavelength of 5000 Å, the wideband diffuser decreases the intensity by a factor of about 350 compared to having no diffuser in the beam. At a wavelength of 3500 Å, the UV diffuser decreases the intensity by a factor of about 40 compared to having no diffuser in the beam. The diffuser is only normally essential for longslit work. Changing the diffuser can *only* be done manually; ask your Support Astronomer.
- Check the mimic to see that the autoguider mirror is in the ULAMPS position.
- Check the mimic to see whether the slit shutter opens and closes during an exposure.
- The echelle gratings have dust covers, which should have been raised at the start of the observing run. The only way to check this is by opening up the thermal enclosure, so only try this after trying everything else first. Only the support astronomer or duty tech should open up the enclosure.
- Check on the mimic display that the camera shutter is out.
- Check on the mimic display that the interface cover is off. The interface cover cannot be moved under computer control; ask your support astronomer or duty tech if it needs to be moved.

7.10.3 No starlight reaching acquisition system

Check the following:

- Check that the dome is not vignetting the telescope. The dome azimuth and telescope azimuth on the telescope status display should be the same. If not, someone has probably turned the dome motors off.
- Check that the primary mirror cover is open, and that the UES Nasymth flat (Nasymth 2 on the engineering console) has been selected.
- Check the mimic to make sure that the dark slide has been opened. The dark slide has to be opened manually; ask your support astronomer or telescope operator.
- Check that the autoguider filter is not in the opaque position (or Nd=5.0 or 3.0!).

7.10.4 No starlight reaching detectors

Check the following:

- Check that the dome is not vignetting the telescope. The dome azimuth and telescope azimuth on the telescope status display should be the same. If not, someone has probably turned the dome motors off.
- Check that the primary mirror cover is open, and that the UES Nasymth flat (Nasymth 2 on the engineering console) has been selected.
- Check the mimic to make sure that the dark slide has been opened. The dark slide has to be opened manually; ask your support astronomer or telescope operator.
- Check the mimic to see that the autoguider mirror is in one of the following positions; `CLEAR, POINTSOURCE, SHORTSLIT, LONGSLIT.`
- Check the mimic to see whether the slit shutter opens and closes during an exposure.
- The echelle gratings have dust covers, which should have been raised at the start of the observing run. The only way to check this is by opening up the thermal enclosure, so only try this after trying everything else first. Only the support astronomer or duty tech should open up the enclosure.
- Check on the mimic display that the camera shutter is out.
- Check on the mimic display that the interface cover is off. The interface cover cannot be moved under computer control; ask your support astronomer or duty tech if it needs to be moved.
- When using IPCS-II, check that the camera shutter is open, after resetting following use of the red panic button.

7.10.5 Telescope drives off object when autoguider loop closed

This is probably because the guide errors generated by the autoguider are being applied in the wrong sense, due to the assumed orientation of the guide probe being wrong. Check the following:

- Has the correct guide probe been selected using the TCS AGSELECT command ?
- Is there a possible error with the positioning of the derotation optics ? Check that the absolute and incremental encoders are reading the same value on the TCS encoders page. Check that with the slit angle set to zero, using the handset to move an object in the Y direction moves it along the slit. See Section 8.1 for more details.
- Could the orientation of the guide fibre itself have been disturbed ? Unlikely, but see Section 8.2 for more details.

Chapter 8

Setup and alignment procedures

8.1 Checking the positioning of the derotator

The TCS is set up so that if the UES focal station is selected with the derotator option enabled (type `UES DEROT` at the TCS), and the slit angle set to zero, the (X,Y) coordinate system used by the handset will always be aligned with the spectrograph slit, regardless of the sky PA. Offsetting a star in Y will move it along the slit, and offsetting it in X should move it perpendicular to the slit.

If there is any evidence that the derotator is not being positioned correctly (if for example attempting to close the autoguider loop results in the telescope driving off the object), the positioning of the derotator can easily be checked by viewing a star on the TV, and checking that the (X,Y) handset works as advertised.

If it doesn't, the first thing to check is that the absolute and incremental encoders are reading the same. Check this on the TCS encoders page (type `PAGE ENC` on the TCS). If they appear different, try zerosetting the incremental encoder by typing `ZERO UES ROT` on the TCS.

If the absolute encoder has been moved, it will be necessary to redetermine the encoder zeropoint. The simplest way to do this is to use the TCS `ZEROSET` command to zeroset the UES derotator to a specified position (i.e. type `ZERO UES ROT TO <position>`). Try different positions until the behaviour of the TCS handset is as advertised above. You will now be able to observe normally. Stop the rotator, and write down the value of both absolute and incremental encoders as displayed on the TCS encoders page, so that the newly determined zeropoint can be set up in the telescope parameter file. You will be able to observe, but until the the zeropoint has been set up in the parameter file, it will be lost each time you shut down and start up the TCS.

N.B. If it is neccessary to redetermine the postion of the absolute encoder, please ensure that Telescope Operator notes this in the WHT Log Book and also enters a fault in the Fault Database.

8.2 Orientation of coarse guide fibre

If an object is visible on the coarse autoguider fibre, then using the TCS handset to offset in the −Y direction should move the image towards the top right of the CCD, and offsetting in the −X direction should move the image towards the bottom right of the CCD; the angle between the autoguider CCD y axis and the TCS handset Y axis is approximately 70 degrees.

If this has changed, it will be necessary to use GSEXAM to modify the TCS variable GUI_GD_ROTATION(3), otherwise the loop cannot be locked. This is the rotation angle of the autoguider CCD in radians, currently set to 1.213 radians (about 70 degrees). Once this has been set correctly, and the autoguider loop succesfully closed, have the constant GUI_GD_ROTATION(GUI_K_UESCOARSE) in the WHT.INI startup file modified and do a slow startup of the TCS.

8.3 Spectrograph focus; adjusting the CCD camera

The CCD camera is routinely setup by the Duty Technician or the Support Astronomer before the start of each run. The Observer should not change the CCD Dewar on the camera mount.

The steps that need to be performed to bring the spectrograph into focus are as follows:

8.3.1 Aligning the CCD Camera for Rotation

In order to ease extraction of the individual spectral orders the CCD camera should be aligned so that the central order runs vertically along the CCD. Note that due to curvature of the echellogram (see Fig. 3.6) it will not be possible to have all the individual orders running vertically. The CCD camera can be rotated; the securing Allen bolts have to be loosened, and the CCD dewar rotated. The rotation position is measured with micrometer D. A change in micrometer reading of +1mm gives a rotation of approximately ?? pixels end to end on the TEK chip.

Before and after each adjustment to the dewar take a short glance exposure with the echelle configured to the wavelength to be used, a tungsten lamp and slit length set to automatic. The commands for this would be:

ICL>	`UCENWAVE31 5000`	Set 31.6 echelle to 5000Å
ICL>	`UMIRROR ULAMPS`	Move mirror to comparison lamps position
ICL>	`ULAMPS W`	Turn on tungsten lamp
ICL>	`USLITWIDTH 1.5 ARCSEC`	Set slit width to about 2–3 pixels
ICL>	`USLITLEN AUTO`	Set slit length automatically
ICL>	`GLANCE UES 2`	Take a glance exposure

Each glance run can be transferred to the SparcStation where the IRAF IMEXAMINE routine can be used to measure the position of the echelle order at the top and bottom of the CCD image.

It may be neccassary to make more than one adjustment to the CCD dewar rotational postion before the echelle orders are satisfactorily aligned on the detector.

8.3.2 Adjusting the CCD Camera for Tilt

It will be neccassary to determine the tilt of the CCD camera and adjust the CCD dewar on the kinematic mount so that it lies coplanar. The CCD dewar tilt can be adjusted by means of the three capstans; A, B and C.

In order to determine the degree of tilt a Hartmann test must first be performed. This involves moving the Hartmann unit into the light path and then taking two arc exposures with the Hartmann shutters in the up and down positions. Measuring the Hartmann shifts at the edges of the detector then gives the degree of tilt. For maximum accuracy the spectrograph must be roughly in focus before carrying out these tests. Hence it may be neccessary carry out the collimator focus as described in the following section before correcting for tilt.

The following commands are required at the ICL prompt in order to take the exposures to measure tilt, issue the following commands at the ICL console (here it is assumed that the echelle has been configured to the desired central wavelength and that the slit length has been set):

ICL>	`UHART IN`	Put Hartmann unit into the beam
ICL>	`UHARTPOS DOWN`	Put in bottom Hartmann shutter
ICL>	`UMIRROR ULAMPS`	Set A&G mirror to comparison lamps position
ICL>	`ULAMPS THAR`	Turn on the ThAr comparison lamp
ICL>	`ARC UES 30 "UHART DOWN 30S"`	Take arc exposure (may need longer or shorter exposure time depending on central wavelength
ICL>	`UHARTPOS UP`	Move upper Hartmann shutter into the beam
ICL>	`ARC UES 30 "UHART UP 30S"`	Take arc exposure

The Hartmann shifts in the positions of the arc lines taken at the edges of the CCD frames should now be determined. At present the easiest way to mesure these shifts is to extract portions of individual orders of the arc from each of the corners of the image and one from the centre. Then collapse these down to form 1-D spectra and cross correlate the corresponding spectra from the 'UP' and 'DOWN' images.

(N.B. At a future date FIGARO and/or IRAF routines will be available to perform these cross-correlations automatically: please check with your Support Astronomer if these routines are available.)

Depending on the degree and direction of the tilt it will be neccessary to adjust the CCD dewar capstans. Below the effects of moving the capstans are indicated:

- A change of +1mm of the A capstan will give a change in the tilt from ?? to ?? of aprroximately ?? pixels
- A change of +1mm of the B capstan will give a change in the tilt from ?? to ?? of aprroximately ?? pixels
- A change of +1mm of the C capstan will give a change in the tilt from ?? to ?? of aprroximately ?? pixels

After having altered the caostan settings, repeat the Hartmann exposures and re-measure the tilt. Some iteration of this procedure may be required before all tilt has been removed.

8.3.3 Adjusting the CCD Camera for Optimal Collimator Focus

The collimator may be adjusted to bring the spectrograph into focus. If the collimator has to be set far from its optimum position astigmatism will result. The optimum collimator position for the *wide* collimator is at about 10000 microns. If best focus is obtained outside of the range 10000 ± 5000 microns then the CCD dewar should be repositioned either further or closer to the camera mount. This is achieved by turning capstans A, B and C by the same amount. As a guide:

- an increase of +1mm on the capstans will give a change in the collimator focus of ?? microns.

For example, if you achieve a focus with the collimator at 20000 microns, changing the capstan settings of A, B and C by ??mm will bring the spectrograph into focus at a collimator position of 10000 microns.

(N.B. Care here in altering the capstans should mean that no further tilt is introduced into the system!)

8.4 Spectrograph focus; adjusting the collimator

This is the final 'fine' focus of the spectrograph. This should be the only stage that the Observer need concern him/herself with as the previous stages will have been performed before the run starts by the Support Astronomer or Duty Technician.

Again, use a Hartmann test to focus the spectrograph. The procedure to follow is outlined above in Sec. 8.3.2 and briefly repeated here:

To carry out the Hartmann test, you will have to set up the calibration unit to illuminate the slit with a comparison lamp. Use a reasonably wide slit (say 2.5 pixels) so that the line profiles are adequately sampled. Move the Hartmann unit in, and take pairs of exposures with the Hartmann shutter up and down for several different collimator settings. Measure the Hartmann shift for each pair of images. There are two ways of doing this:

- The faster but less accurate approach is to use the DMS Y–FIND function. Once each image has been displayed on the DMS, type Y–FIND on the DMS keyboard, position the cursor on a bright/isolated/unsaturated line close to the centre of the detector, and hit return. The DMS will display the line profile and calculate the line centroid. The Hartmann shift is equal to the difference in the line centroid between each pair of images.
- A slower but more accurate approach is to transfer the data to the VAX, and use FIGARO to cross-correlate each image pair. Use the FIGARO EXTRACT routine to extract spectra from close to the centre of each image, and use SCROSS to cross-correlate the resulting spectra to obtain the Hartmann shift.

Plot the Hartmann shift as a function of focus, determine the value of the focus for which the shift is zero, and move the collimator to that position. Check the focus by taking a further pair of exposures with the Hartmann shutter up and down, and check that the Hartmann shift is close to zero.

It may be useful to know that a Hartmann shift of one pixel corresponds to a shift of about 4000 μm on the UV collimator and about 3600 μm on the wideband collimator. If cross-correlating the spectrum taken with the Hartmann shutter up with the spectrum taken with the Hartmann down (FIGARO command SCROSS ¡up-file¿ ¡down-file¿) produces a negative shift, then the collimator focus needs to be increased.

The spectrograph focus depends on which collimator is being used (UV or wideband) and which focal modifier lens is being used (red, blue or none). If either the collimator or the focal modifier lens is changed, then it is necessary to apply an offset to the collimator focus. Fortunately the focus is not wavelength dependent, so the offset is constant. The offsets are summarised in Table 8.1.

Table 8.1: Offsets to spectrograph focus

Collimator	Focal modifier	Offset to add to collimator focus (microns)
Wide	None	0
UV	None	−1700

N.B. In practice UES is not used with a focal modifier lens hence the only offset of importance is when the collimator is changed from Wide to UV (see sec. ??).

In Spring 1994 an automatic ICL> focus procedure will be avaliable (probably to be called UES_FINEFOCUS). This will take up and down Hartmann exposures at a range of collimator positions and determine the optimum collimator position at best focus. Please check with the Support Astronomer for availability.

Chapter 9

Command reference section

9.1 Command reference section

This section contains a detailed description of the commands available for controlling UES and its A&G unit from ICL. The order of the commands roughly follows the light-path from the telescope to detector.

Notation:

- Examples of commands entered at the terminal are in typewriter font: `USLITWIDTH 50`;
- Angle brackets denote parameter values or character strings: $<$`angle`$>$;
- Square brackets denote optional input: `[x,y]`; all other parameters are obligatory;
- The command names are also referred to as 'mechanism names', e.g. the `UES_INIT` command.

9.1.1 Acquisition, comparison and autoguider mirror

9.1.1.1 UMIRROR

Moves autoguider mirror in UES A&G unit

Format:	`UMIRROR <parameter>`
Parameter:	The position of the mirror. This can be a real number specifiying the linear displacement of the mirror, or a character string specifying one of a set of standard operational positions.
Units:	mm or none
Range:	$0 <$ `<parameter>` < 406, or one of the following character strings: CLEAR, GUIDEONLY, POINTSOURCE, LONGSLIT, SHORTSLIT, ULAMPS.
Defaults:	Defaults to uninitialised on power–up. Initialises to position 203 mm.
Examples :	`UMIRROR 0, UMIRROR POINTSOURCE`
Comments:	The standard operational positions of this autoguider mirror have the following effect: CLEAR allows all the light through to the spectrograph slit, and is the position required when the observer wishes to use the TV to view the slit. GUIDEONLY directs all the light to the offset guide probes. POINTSOURCE, LONGSLIT and SHORTSLIT allow light from an object at the field centre to reach the slit, and direct light in the outer part of the field to the offset guide probe. ULAMPS directs light from the comparison lamp system into the spectrograph. The positions CLEAR, GUIDEONLY, POINTSOURCE, LONGSLIT, SHORTSLIT, ULAMPS correspond to linear displacements of the mirror of 0, 83, 138, 225, 312 and 406 mm respectively.

9.1.2 Autoguide probe

9.1.2.1 UAGX

Sets X coordinate of autoguide probe

Format:	`UAGX <parameter>`
Units:	microns
Range:	0 < `<parameter>` < 73600
Defaults:	Defaults to uninitialised on power-up. Initialises to
Examples :	`UAGX 30000`
Comments:	

9.1.2.2 UAGY

Sets Y coordinate of autoguide probe

Format:	`UAGY <parameter>`
Units:	microns
Range:	0 < `<parameter>` < 73200
Defaults:	Defaults to uninitialised on power-up. Initialises to
Examples :	`UAGY 30000`
Comments:	

9.1.2.3 UAGXY

Sets X and Y coordinates of autoguide probe

Format:	`UAGXY <parameter1> <parameter2>`
Units:	microns
Range:	0 < `<parameter1>` < 73600 0 < `<parameter2>` < 73200
Defaults:	Defaults to uninitialised on power-up. Initialises to
Examples :	`UAGXY 20000 25000`
Comments:	This is equivalent to using UAGX and UAGY separately

9.1.2.4 UGDXY

Moves the autoguide probe to the appropriate coordinates to pick up an offset guide star seen on the slit-viewing TV.

Format:	`UGDXY <parameter1> <parameter2> <parameter3>`
Parameter1:	Which guide probe to use (COARSE or FINE)
Parameter2:	X coordinate of star on TV (pixels)
Parameter3:	Y coordinate of star on TV (pixels)
Examples :	`UGDXY COARSE 194 271`
Comments:	

9.1.2.5 UAGFOC

Sets focus of autoguide probe

Format:	`UAGFOC <parameter>`
Units:	microns
Range:	0 < `<parameter>` < 200
Defaults:	Defaults to uninitialised on power-up. Initialises to
Examples :	`UAGFOC 100`
Comments:	

9.1.2.6 UAUTOFILT

Selects autoguider filter
Format: `UAUTOFILT <parameter>`
Units: None
Range: 1 < `<parameter>` < 12 or filter name
Defaults: Defaults to uninitialised on power-up.
Initialises to
Examples : `UAUTOFILT 6, UAUTOFILT GG495`
Comments:

9.1.2.7 UAUTONAME

Sets names of filters in autoguider filter wheel
Format: `UAUTONAME`
Comments: The procedure sets up default names, then prompts for the name and position of each filter.

9.1.3 Comparison system

9.1.3.1 ULAMPS

Turns comparison lamps on or off
Format: `ULAMPS <parameter>`
Parameter: Lamp names separated by +, OFF turns all lamps off.
Defaults: Defaults to off on power-up.
Examples : `ULAMPS THAR, ULAMPS D+W, ULAMPS OFF`
Comments: This command switches on or off the requested lamps, and opens or closes the corresponding lamp shutters.

9.1.3.2 ULAMPSHUT

Sets state of shutters on lamp-houses
Format: `ULAMPSHUT <parameter>`
Parameter: Lamp names separated by +, CLOSE closes all shutters.
Defaults:
Examples : `ULAMPSHUT W`
Comments: This command only controls the lamp shutters, not the lamps themselves.

9.1.3.3 ULAMPNAME

Sets names of comparison lamps mounted.
Format: `ULAMPNAME`
Comments: The procedure sets up default names, then prompts for the name and position of each lamp.

9.1.3.4 UCOMPFILTND

Selects neutral density filter for comparison lamps
Format: `UCOMPFILTND <parameter>`
Units: None
Range: 1 < `<parameter>` < 12 or filter name
Defaults: Defaults to uninitialised on power–up
Examples : `UCOMPFILTND 6, UCOMPFILTND ND3.0`
Comments:

9.1.3.5 UCNNAME

Sets names of neutral density filters for comparison lamps

Format: `UCNNAME`

Comments: The procedure sets up default names, then prompts for the name and position of each filter.

9.1.3.6 UCOMPFILTC

Selects colour filter for comparison lamps

Format: `UCOMPFILTC <parameter>`

Units: None

Range: 1 < `<parameter>` < 12 or filter name

Defaults: Defaults to uninitialised on power–up

Examples : `UCOMPFILTC 6, UCOMPFILTC R`

Comments:

9.1.3.7 UCCNAME

Sets names of colour filters for comparison lamps

Format: `UCCNAME`

Comments: The procedure sets up default names, then prompts for the name and position of each filter.

9.1.4 A&G main filter wheels

9.1.4.1 UFILTPOL

Moves main polariser wheel in UES A&G unit

Format: `UFILTPOL <parameter>`

Units: None

Range: 1 < `<parameter>` < 11 or component name

Defaults: Defaults to uninitialised on power–up

Examples : `UFILTPOL 6, UFILTPOL POLAROID`

Comments:

9.1.4.2 UFPNAME

Sets names of components in main polariser wheel

Format: `UFPNAME`

Comments: The procedure sets up default names, then prompts for the name and position of each component.

9.1.4.3 UFILTND

Moves main neutral density filter wheel in UES A&G unit

Format: `UFILTND <parameter>`

Units: None

Range: 1 < `<parameter>` < 11 or filter name

Defaults: Defaults to uninitialised on power–up

Examples : `UFILTND 6, UFILTND ND3.0`

Comments:

9.1.4.4 UFNNAME

Sets names of filters in main neutral density filter wheel

Format: `UFNNAME`

Comments: The procedure sets up default names, then prompts for the name and position of each filter.

9.1.4.5 UFILTC

Moves main colour wheel in UES A&G unit
Format: `UFILTC <parameter>`
Units: None
Range: 1 < `<parameter>` < 11 or filter name
Defaults: Defaults to uninitialised on power–up
Examples : `UFILTC 6, UFILTC B`
Comments:

9.1.4.6 UFCNAME

Sets names of filters in main colour filter wheel
Format: `UFCNAME`
Comments: The procedure sets up default names, then prompts for the name and position of each filter.

9.1.5 UES Slit-area

9.1.5.1 USLITANGLE

Sets the UES slit angle
Format: `USLITANGLE <parameter>`
Units: Millidegrees
Range: -12000 < `<parameter>` < 11400
Defaults: Defaults to uninitialised on power–up
Examples : `USLITANGLE 500`
Comments: The slit angle mechanism has insufficent range to be set vertical over the entire wavelength range. The effect will be that the slit will be slightly tilted with respect to its optimum orientation. However this can be corrected for by data reduction software.

9.1.5.2 USLITWIDTH

Sets the UES slit width
Format: `USLITWIDTH <parameter> <units>`
Units: ARCSEC, MICRON, PIX
Range: 20 < `<parameter>` < 20000 microns
Defaults: Defaults to uninitialised on power–up
Examples : `USLITWIDTH 50`
Comments: The slitwidth can be specified in microns at the slit, arcsec on the sky, or projected pixels on the detector. In order to calculate the slitwidth in pixels, the pixelsize must have been specified using the PIXSIZE command.

9.1.5.3 USLITSHUT

Opens or closes the UES slit shutter
Format: `USLITSHUT <parameter>`
Units: None
Range: 0, 1, OPEN, CLOSE
Defaults: Defaults to uninitialised on power–up
Examples : `USLITSHUT 0`

Comments: This command is only provided for test purposes. During normal operation the shutter is controlled by the detector. This command may be useful for closing the shutter if it does not close properly at the end of an exposure.

9.1.5.4 UEXPOSE

Opens the UES slit shutter for a specified time

Format: `UEXPOSE <parameter>`
Units: millisecs
Range: 1500 < `<parameter>` < 640000
Examples : `UEXPOSE 50000`
Comments: This command is only provided for test purposes, or for timing exposures with non-standard detectors. During normal operation the shutter is controlled by the CCD or the IPCS detector.

9.1.5.5 UDEKKER

Sets the position of the UES dekker, which controls the UES slit length.

Format: `UDEKKER <parameter>`
Units: Microns
Range: 0 < `<parameter>` < 123530
Defaults: Defaults to uninitialised on power–up
Examples : `UDEKKER 100000`
Comments: The USLITLEN command should normally be used instead of the UDEKKER command.

9.1.5.6 USLITLEN

Sets the UES slit length, by moving the dekker.

Format: `USLITLEN <parameter> <units>`
Units: ARCSEC, MM, PIX
Defaults: Defaults to uninitialised on power–up
Examples : `USLITLEN 5 ARCSEC, USLITLEN 20 MM`
Comments: The slitlength can be specified in mm at the slit, arcsec on the sky, or projected pixels on the detector. In order to calculate the slitlength in pixels, the pixelsize must have been specified using the PIXSIZE command.
`USLITLEN AUTO` automatically determines appropriate slitlength according to echelle and central wavelength combination in use.

9.1.5.7 UMODLENS

Selects the UES focal modifier lens.

Format: `UMODLENS <parameter>`
Units: None
Range: 1 < `<parameter>` < 7 or name of component
Defaults: Defaults to uninitialised on power–up
Examples : `UMODLENS 5, UMODLENS BLUE`
Comments: The red and blue focal modifier lenses mounted in this wheel convert the f/11 telescope beam to f/13.9. With the focal modifier lenses in, there is no overfilling of the echelle; note that this is opposite to the case of the UCLES spectrograph.

9.1.5.8 UFMNAME

Sets names of lenses in focal modifier wheel

Format: `UFMNAME`
Comments: The procedure sets up default names, then prompts for the name and position of each lens

9.1.6 UES collimator and Hartmann unit

9.1.6.1 UCOLL

Selects the UES collimator
Format: `UCOLL <parameter>`
Units: None
Range: 1, 2, WIDE or UV
Defaults: Defaults to uninitialised on power–up
Examples : `UCOLL WIDE`
Comments:

9.1.6.2 UFOCUS

Sets the UES collimator focus
Format: `UFOCUS <parameter>`
Units: Microns
Range: 0 < `<parameter>` < 20000
Defaults: Defaults to uninitialised on power–up
Examples : `UFOCUS 500`
Comments:

9.1.6.3 UHART

Moves the Hartmann unit in or out of the beam.
Format: `UHART <parameter>`
Units: None
Range: 0, 1, OUT or IN
Defaults: Defaults to uninitialised on power–up
Examples : `UHART 0`
Comments:

9.1.6.4 UHARTPOS

Selects the position of the Hartmann shutter
Format: `UHARTPOS <parameter>`
Units: None
Range: 0, 1, 2, 3, 4, UP, LEFT, DOWN, RIGHT, ROTATE
Defaults: Defaults to uninitialised on power–up
Examples : `UHARTPOS 1`
Comments: Note that if continuous rotation is selected (`<parameter>` = ROTATE or 4), it may not be possible to stop it.

9.1.7 UES prism

9.1.7.1 UPRISM

Moves prism table in or out of the beam. *This command has been disabled, by disconnecting the motor.*
Format: `UPRISM <parameter>`
Units: None
Range: 0, 1, OUT or IN
Defaults: Defaults to uninitialised on power–up
Examples : `UPRISM IN`
Comments: With the prism out of the beam, a flat mirror is in the beam.

9.1.7.2 UPRISMPOS

Sets the prism position

Format:	`UPRISMPOS <parameter>`
Units:	0.1 mm
Range:	0 < `<parameter>` < 2400
Defaults:	Defaults to uninitialised on power–up
Examples :	`UPRISMPOS 500`
Comments:	

9.1.8 UES echelles

9.1.8.1 UECHELLE

Selects which echelle grating is in the beam.

Format:	`UECHELLE <parameter>`
Units:	None
Range:	1, 2, E31, E79
Defaults:	Defaults to uninitialised on power–up
Examples :	`UECHELLE E31`
Comments:	

9.1.8.2 UTHETA31

Sets theta (tilt angle) for the 31.6 grooves/mm echelle

Format:	`UTHETA31 <parameter>`
Units:	Millidegrees
Range:	−2500 < `<parameter>` < 2500
Defaults:	Defaults to uninitialised on power–up
Examples :	`UTHETA31 1000`
Comments:	

9.1.8.3 UTHETA79

Sets theta (tilt angle) for the 79.0 grooves/mm echelle

Format:	`UTHETA79 <parameter>`
Units:	Millidegrees
Range:	−2500 < `<parameter>` < 2500
Defaults:	Defaults to uninitialised on power–up
Examples :	`UTHETA79 1000`
Comments:	

9.1.8.4 UGAMMA31

Sets gamma (rotation angle) for the 31.6 grooves/mm echelle

Format:	`UGAMMA31 <parameter>`
Units:	Millidegrees
Range:	-2290 < `<parameter>` < 2290
Defaults:	Defaults to uninitialised on power–up
Examples :	`UGAMMA31 1000`
Comments:	

9.1.8.5 UGAMMA79

Sets gamma (rotation angle) for the 79.0 grooves/mm echelle

Format:	`UGAMMA79 <parameter>`
Units:	Millidegrees

Range: -2290 < `<parameter>` < 2290
Defaults: Defaults to uninitialised on power–up
Examples : `UGAMMA79 1000`
Comments:

9.1.9 UES camera

9.1.9.1 UCAMLAMP

Switches flatfielding LEDs in camera on
Format: `UCAMLAMP <parameter>`
Units: None
Range: 0, 1, 2, OFF, ON1, ON2
Defaults: Defaults to uninitialised on power–up
Examples : `UCAMLAMP 1`
Comments: Lamp 1 is a yellow LED, intended for use with the IPCS, whilst lamp 2 is a red LED, intended for use with the CCD

9.1.9.2 UCAMSHUT

Opens or close the camera shutter.
Format: `UCAMSHUT <parameter>`
Units: None
Range: 0, 1, OPEN or CLOSE
Defaults: Defaults to closed on power–up
Examples : `UCAMSHUT 0`
Comments: This is a safety shutter, which opens slowly but closes fast. It is not normally used for timing exposures.

9.1.9.3 UPINMASK

Opens or closes the pinhole mask camera shutter.
Format: `UPINMASK <parameter>`
Units: None
Range: 0, 1, OUT or IN
Defaults: Defaults to uninitialised on power–up
Examples : `UPINMASK 0`
Comments: The pinhole mask is intended to be illuminated with the flatfielding LED, when a pattern of reference marks will be projected onto the detector. This makes it possible to determine detector distortion.

9.1.9.4 UPIXEL

Sets pixel size in slit width and slit length directions — as used to calculate projected slitlength, slitwidth and dispersion
Format: `UPIXEL <parameter1> <parameter2>`
Units: Microns
Range:
Defaults: Defaults to 22.5×22.5 microns on power–up
Examples : `UPIXEL 22.0 22.0`
Comments: Set the pixel size in the x and y directions, $x \neq y$ for detectors with rectangular detector elements such as IPCS-II.

9.1.10 Temperature control

9.1.10.1 UTEMP

Reads all 8 UES temperature sensors
Format: `UTEMP`

9.1.11 Initialisation, status and cancel commands

9.1.11.1 UES_INIT

Initialise specified mechanism
Format: `UES_INIT <parameter>`
Units: None
Parameter: Any individual mechanism name, or ALL, NAG or UES
Examples : `UES_INIT USLITWIDTH`
Comments: If ALL is specified, all mechanisms are initialised. If NAG is specified, only A&G mechanisms are initialised, and if UES is specified, only spectrograph mechanisms are initialised. Note that initialisation of all UES mechanisms is slow.

9.1.11.2 UES_UPDATE

Gets status of specified mechanism and updates the ICL MIMIC display.
Format: `UES_UPDATE <parameter>`
Units: None
Parameter: Any individual mechanism name, or ALL, NAG, UES or TEMP
Examples : `UES_UPDATE USLITWIDTH`
Comments: If ALL is specified, status is obtained for all mechanisms are initialised. If NAG is specified, status is only obtained for A&G mechanisms, and if UES is specified, status is only obtained for spectrograph mechanisms. If TEMP is specified, then all temperature sensors are read.

9.1.11.3 UES_CANCEL

Cancels ADAM action on specified mechanism
Format: `UES_CANCEL <parameter>`
Units: None
Parameter: Any individual mechanism name.
Examples : `UES_CANCEL USLITWIDTH`
Comments:

9.1.11.4 UNAMES

Sets up names of components in all filter wheels.
Format: `UNAMES`
Comments: The procedure sets up default names, then prompts for the name and position of any component differing from the default.

9.2 Commands for instrument configuration

This section contains a detailed description of the commands available from ICL for more complex configuration of UES and its A&G unit.

9.2.1 Acquisition procedures

9.2.1.1 UTVVIEW

Configures UES and A&G for viewing the field using the ISEC TV.

Format: `UTVVIEW`

Examples : `UTVVIEW`

Comments: This command moves the A&G mirror to the field viewing position, sets the slit angle to zero, moves the dekker out of the beam, and moves all three A&G main filter wheels to position 1

9.2.1.2 UENDTVVIEW

Re-configures UES and A&G for *after* viewing the field using the ISEC TV.

Format: `UENDTVVIEW`

Examples : `UENDTVVIEW`

Comments: This command re-sets the slit angle, dekker and all three A&G main filter wheels to the positions that they had before using the `UTVVIEW` command.

9.2.1.3 UPROBEVIEW

Configures A&G for viewing the field centre using the coarse autoguider probe.

Format: `UPROBEVIEW`

Comments: This command moves the A&G mirror so that all light is directed to the autoguider (x,y) table, then moves the autoguider coarse probe to the field centre.

9.2.2 Spectrograph configuration

9.2.2.1 UCENWAVE31

Configures spectrograph for a specified central wavelength and order number, assuming the 31.6 l/mm grating is being used.

Format: `UCENWAVE31 <parameter1> [parameter2]`

Parameter1: Central wavelength

Units1: Angstrom

Parameter2: Order number

Units2: None

Examples : `UCENWAVE31 5000 0`

Comments: The correct echelle will be moved into the beam if it is not already there. If the order number is left out, or is equal to 0, then the blaze peak will be chosen. This command alters the two echelle angles and prism translation in order to select the central wavelength, changes the slit angle to get it vertical on the detector, and selects the UV or wideband collimator.

9.2.2.2 UCENWAVE79

Configures spectrograph for a specified central wavelength and order number, assuming the 79.0 l/mm grating is being used.

Format: `UCENWAVE79 <parameter1> [parameter2]`

Parameter1: Central wavelength

Units1: Angstrom

Parameter2: Order number

Units2: None

Examples : `UCENWAVE79 5000 0`

Comments: The correct echelle will be moved into the beam if it is not already there. If the order number is left out, or is equal to 0, then the blaze peak will be chosen. This command alters the two echelle angles and prism translation in order to select the central wavelength, changes the slit angle to get it vertical on the detector, and selects the UV or wideband collimator.

9.2.2.3 USLITOFF

Applies an offset to the slit angle as calculated from the spectrograph model.
Format: `USLITOFF <parameter1>`
Parameter1: Offset to apply to angle
Examples : `USLITOFF 1234`
Comments: Offset is measured in MDEG—see sec. 3.3.2 for use of this offset.

9.2.2.4 UTHETAOFF

Applies an offset to the value of theta as calculated from the spectrograph model.
Format: `UTHETAOFF <parameter1> <parameter2>`
Parameter1: Offset to apply to angle
Parameter2: Units of offset (MDEG or PIX)
Examples : `UTHETAOFF 1234 MDEG`
Comments: See sec. 3.3.2 for use of this offset.

9.2.2.5 UGAMMAOFF

Applies an offset to the value of gamma as calculated from the spectrograph model.
Format: `UGAMMAOFF <parameter1> <parameter2>`
Parameter1: Offset to apply to angle
Parameter2: Units of offset (MDEG or PIX)
Examples : `UTHETAOFF 1234 MDEG`
Comments: See sec. 3.3.2 for use of this offset.

Chapter 10

ECHWIND

10.1 Introduction to ECHWIND

A full description of the use of ECHWIND can be found in Starlink User Note No. ??

10.2 Use of ECHWIND at the WHT

*** Include details from the user guide, quick reference here only ***

Chapter 11

Data reduction

11.1 ECHOMOP

The ECHOMOP package provides facilites for the extraction of spectra from 2D-data frames, such as those typically provided using Echelle spectographs. The package was written primarily for the reduction of data from the UCL Echelle Spectograph (installed on the AAT), but is sufficiently flexible to process data from a wide variety of instruments producing 2-D multi-order/object spectra.

A substantial degree of automation is provided, particularly in the traditionally manual functions for cosmic ray contamination detection, and arc line wavelength calibration. The automated functions can also be overridden by interactive alternatives when required. Features include robust and flexible order tracing, optimal extraction, support for variance arrays, and 2-D distortion fitting and extraction.

In the interests of maximum flexibility the package provides both a highly interactive shell task which guides the user through the operations usually required, as well as providing unitary tasks for all significant operations, allowing the construction of powerful batch reduction jobs for processing multiple frame datasets. Facilities for automated archiving of results, and flexible transport of models between different reductions are also provided.

The package was developed under funding from the S.E.R.C. and has benefitted from constant involvement with the personnel of the Optical Science Labarotory (at UCL) where the UCLES instrument was designed and built. The current implementation uses the FIGARO environment as installed at all UK STARLINK sites, and an ADAM version is being produced.

11.1.1 Introduction

This version of the package runs under the FIGARO environment, and this environment must be set up before the programs can be used. The package is prepared for use by typing the command

```
ECHOMOP_SETUP
```

at the system command prompt ($ on a VMS system). The setup procedure sets up any environments required (eg FIGARO), and then lists the commands which are available for reduction.

New users can obtain an on-line introduction to the use of the package by typing the command

```
@ECHOMOP_SOURCE:ECH_DEMO
```

This runs a demonstration reduction using a set of included data frames. It demonstrates the main functions of the package and traces a simple reduction from start to the production of an extracted, wavelength calibrated spectrum.

11.1.2 Preparing for a reduction

The frames neccesary for the reduction should be first converted into FIGARO standard data files. FIGARO contains a set of tape reading and format translation utilities to help you do this. Any pre-reduction processing as outlined above should then be performed on the raw data frames.

In addition it may then be neccesary to rotate all the frames through 90 degrees to ensure that the orders run mainly parallel to the frame rows.

11.1.3 Starting up

ECHOMOP may be used in a variety of ways depending upon the expertise of the user.

The most convenient method for normal use is to start the main ECHOMOP task itself. This task provides a guided path through the processes in a standard reduction.

ECHOMOP is a menu driven program which drives all the other programs in the package. ECHOMOP will always provide a default for the next task to be performed, and this will usually be the correct one for a standard reduction. To accept the recommeded next step , it is only necessary to hit /return/.

The package uses a disc based 'reduction file' to pass objects between its various component tasks. The user will initially be asked to provide a filename for this file , which will be created in the current directory. This file is permanently associated with a particular set of data frames (object,arc,flat etc.) thereby providing the ability to replay any aspect of the reduction at a later date. Reduction files can occupy a large amount of disk space however, and many users will wish to delete them as soon as the reduced spectrum has been obtained.

To start a reduction type

```
ECHOMOP
```

at the command line ($) prompt.

11.1.4 A standard reduction

The simplest method of using the package is via the monolithic task ECHOMOP which has access to all the processing modules, along with a set of utilities along interactive tuning of parameters, and plotting of graphs of intermediate results. As reduction progresses, the details and results of each task are stored in a disk file allowing the user to repeat/alter any aspect of the reduction at any stage.

The package prompts the user for the name of this 'reduction structure' file when it starts. If the name of an existing reduction-structure file is entered then this file will be opened, otherwise the package will create a new file using the name provided. The name of the file may also be provided on the startup command line. Eg:

```
ECHOMOP ECH_RDCTN=<filename>
```

Once the reduction-structure file has been opened the main menu is presented. This menu consists of all the major steps in the reduction process, along with a set of utility options, and some more specialised options (Eg. 2-D distortion correction). An option is selected by typing its number followed by carriage return. Some options may also be selected by entering a keyword (or its first character) followed by carriage return. Eg. `PLOT` or `P` would select the graph plotting utility. The package attempts to provide the most sensible option (for a standard reduction) as the default, and the user can accept this simply by typing a carriage return. Option `0` always provides help information on the default option, and then allows the user to browse the help library for more detailed information. Most options invoke processing modules. These modules will usually require the specification of a number of parameters which will be automatically prompted for by the program. It is possible to preview/edit the parameters for any option by entering its number prefixed by a minus sign. Eg. -3 would allow preview/edit of the parameters used by option 3.

N.B. In general, once a parameter has been provided by the user it will *not* be re-prompted for by any module which requires it. The modules will simply re-use the value already supplied. The -option strategy overrides this behaviour and allows the user to change any parameter at any point.

All parameters can optionally be provided on the startup command line, in which case the modules will use the value provided without prompting.

11.1.5 Standard steps

The following steps constitute a standard reduction as implemented by the monolithic ECHOMOP task. The user can follow this sequence by hitting carriage return at each main menu prompt, and supplying data frame names and parameters when they are prompted for.

1	=	Start a reduction
2	=	Trace the orders and fit polynomials
3	=	Clip polynomial fits
4	=	Determine dekker/object limits
5	=	Model flat field per-pixel balance factors
6	=	Model sky background
7	=	Model object profile
8	=	Extract object and arc spectra
9	=	Locate arc lines and fit gaussian profiles
10	=	Identify arc lines and fit wavelength scales
11	=	Model blaze profile and apply to object spectrum
12	=	Scrunch object spectrum
14	=	Write results file

The demonstration provided by `ECH_DEMO` follows this sequence and the reader is encouraged to try it before using the package in earnest.

Steps 9 through 12 would be omitted if no wavelength calibration was required. Step 5 would be omitted if no flat field was available.

In cases where multiple object frames have been taken, it would be efficient to use only steps 6,7,8,11,12 for additional frames.

A quick look extraction may be performed as soon as step 4 has been completed (option 20).

11.1.6 Parameters and prompts

Most of the information required by ECHOMOP from the user is obtained using the FIGARO parameter system. This standard method of obtaining values leads to a consistency of user interace between all FIGARO based tasks. However in some cases it is more convenient to present the user with a menu of choices and this approach is used for the top level selection of processing steps , and also during interactive graphics intensive steps.

When a FIGARO parameter is prompted for, the default value is indicated enclosed in [ ] brackets. As well as entering a value the user may also use the following special responses which are processed by the FIGARO parameter system :

- ? provides information on parameter type, minimum and maximum allowed values etc.
- ?? provides same information as above plus any detailed help text available.
- !! requests an abort of the task
- Backslash causes all subsequent parameters to adopt their default values *without* further prompts.

11.1.7 Tuning parameters

The ECHOMOP uses a number of 'hidden' parameters. These quantities will not normally need to be changed, but provide a greater flexiblity when processing problem data. They are also used by ECHOMOP to configure itself for 'quick-look' extraction.

The `ECH_TUNER` option/task allows the user to interactively examine and alter any of these parameters. They may also be supplied on tasks command lines. By default ECHOMOP tasks always indicate the values of any `TUNE_` parameters which have been set differently from the hard-coded defaults.

Appendix A

Filter transmission

Figure A.1: Transmission of main beam colour filters

Figure A.2: Transmission of main beam ND filters

Figure A.3: Transmission of autoguider filters

Figure A.4: Transmission of comparison colour filters

Figure A.5: Transmission of comparison ND filters

Appendix B

UES and Nasmyth A&G manuals

```
Below an extract from my system overview in the technical manuals. Is this
a suitable appendix?????          Jaap
```

UES was constructed in Utrecht, NAG in Roden. Detectors, the kernel of the 4MS system, most peripherals and the VAX software are of RGO origin. Manuals are therefore many and varied. Those listed below concern UES and NAG.

B.1 System

- Users' manual (Steve Unger, Max Pettini, Nic Walton). This manual.
- Duty-tech manual (Jaap Tinbergen). Introduction and diagnostic procedures.
- Quick Reference Guide (Jaap Tinbergen). Detailed information for fault diagnosis via 4MS.
- 4MS (Jaap Tinbergen). A single 4MS drives both UES and NAG. Description of the system, and a listing of the FORTH screens.
- VAX-to-4MS interface description 'WHT-UES-1' (Marion Fisher).
- 4MS Reference manual (Ben Murdin); RGO reference manual.
- Kernel description for ISIS 4MS system (Alan Popplestone, John Maclean); RGO reference manual. The UES/NAG kernel is an adaptation of that for ISIS.

B.2 UES

- General description (Jaap van Nieuwkoop; substantial contributions by Ton Schoenmaker and Jan Willem Pel). Contains a wealth of mechanical and optical detail, with detailed alignment and adjustment procedures.

- Electronic manuals (Jacques van Amerongen and Gerard van Gelder):
  - Control system: introduction to UES and its control system ('Grey Book')
  - Assemblies: descriptions, diagrams, photographs of the main units of UES ('Blue Book')
  - SECU (Standard Electronic Control Unit): description and circuit diagrams of all p/c boards ('Green Book')
  - SECU microprocessor software: describes the interactions of mechanisms, SECU and 4MS ('Red Book')
  - PC software aids: tests and diagnostics using the Utrecht-supplied PC 'Charly' ('Orange Book')
  - Temperature measurement box: descriptions, diagrams ('Thin Green Book')
- Mechanical drawings (several volumes; Ruud van Stappershoef and Mari Hanegraaf)
- Tamson/Neslab: details of the commercial cooler-heater system

B.3 NAG

- System overview (Jaap Tinbergen).
- Optics (Jaap Tinbergen). Description of principles and component specifications.
- Mechanics (Arie de Jong, Hans Hendriksen). Description and 3 volumes of reduced-size AUTOCAD drawings.
- Electronics (Bob Rijf, Aad van der Helm, Sieds Damstra). Description and 2 volumes of diagrams, connector and cable listings.
- Barcode reader module (Alan Popplestone). Standard RGO.
- Comparison lamp supply (John Maclean). Standard RGO.

```
NIC,   PLEASE,  IF YOU THINK SUCH A LISTING OF MANUALS IS A GOOD IDEA,

add references to manuals for TCS, CCD controllers, ADAM, CFS, ICL, DMS,
Autoguider VME and what have you.
```

Appendix C

Focal modifier lenses

)

C.1 Principles of operation

When designing a spectrograph it is necessary to decide how to match the size of the collimated beam, which is elliptical in shape, to the size of the grating, which is rectangular in shape. Two possible solutions are:

- Extreme underfilling of the grating. The normal approach is for the diameter of the collimated beam to be equal to the size of the grating. This means that the corners of the grating are not illuminated.

- Extreme overfilling of the grating. An alternative is for the entire grating to be illuminated. However, in order to illuminate the corners of the grating with a circular beam, the diameter of the beam must be larger than the size of the gratig, and hence some light will be lost at the edge of the beam.

Solutions intermediate between these two extremes are also possible. There are two options available with the UES. With the focal modifier lenses out of the beam, the input f/ratio of f/11.1 results in a collimated beam of diameter 215 mm. The effect of inserting the focal modifier lenses into the beam is to modify the f/ratio of the telescope beam to f/13.9, resulting in the diameter of the collimated beam being reduced to 172 mm. Both of these options result in some overfilling of the grating, as summarised in Table C.1.

It can be seen that the light lost due to overillumnation is greater with the lens out of the beam; the geometrical efficency of the instrument without the lens is 80 per cent of that with the lens.

It should be noted that the effect of the UES focal modifier lenses is precisely opposite to the effect of the UCLES focal modifier lenses. The UES focal modifier lenses decrease the degree of overillumination, whereas the UCLES focal modifier lenses increase it.

Inserting the focal modifier lenses can either increase or decrease the overall throughput of the spectrograph, for the following reasons.

Table C.1: Properties of focal modifier lenses

	Without focal modifier	With focal modifier
Input focal ratio	f/11.1	f/13.9
Collimated beam diameter (mm)	215	172
Light loss at echelle (per cent)	31	14

- The collimated beam in UES overfills the grating. With the focal modifiers in the beam, the beam diameter is larger, and so light losses at the grating due to overfilling are also larger.
- The demagnification factor, which depends on the ratio of the collimator to the camera focal lengths, increases with the focal modifier lenses in the beam. It is therefore possible to use a larger entrance slit, whilst keeping the slitwidth projected onto the detector constant, so preserving spectral resolution, and reducing slit losses.
- We expect there will be losses associated with the focal modifier lenses themselves.

The choice of whether or not to use the lenses depends on which of these effects dominates, as discussed in the next section.

C.2 Performance of the modifier lenses

We noted above that the geometrical efficency of the instrument without the focal modifier lens is 80 per cent of that with the lens. In other words, inserting the focal modifier lenses increases the geometrical efficency of the instrument by 25 per cent. At first sight it would therefore seem best to operate the instrument with the lens in the beam.

However, removing the lens increases the input f/ratio of UES from f/11.1 to f/13.9, and makes it possible to increase both the slit length and the slit width by 13.9/11.1, a factor of 1.25, whilst leaving the resolution at the detector constant. The gain this provides in spectrograph efficiency depends on the type of object being observed. For a spatially extended source, where the amount of emission detected is limited both by the slit length and the slitwidth, the improvement in slit-losses is 1.25^2, or an extra 50 per cent. For stellar work, slit-losses are due to broadening of the image by seeing, and depend on the ratio of the seeing FWHM to the slitwidth; in this case we can expect gains of up to 25 per cent, depending on the seeing.

The other reason for for removing the lens is that the transmission of the lens is low. The transmission was measured by illuminating the slit with a diffuse source of light. Spectra were taken with the focal modifer lenses both in and out of the beam, adjusting the slitwidth and length as described above. Under these circumstances we expect the spectrum taken without the focal modifier lenses in the beam to be 25 per cent brighter than the spectrum with the focal modifier lenses in the beam (a 50 per cent increase due to the larger slit, partially offset by a 20 per cent reduction due to overfilling of the grating)

In practice we found that at all wavelengths the spectra taken without the focal modifier lenses in the beam were over 50 per cent brighter than the spectra with the focal modifier lenses in the beam. For the red focal modifier lenses, between 5000 and 7000 Å, the factor was even larger.

This result implies losses due to the focal modifiers themselves of at least 20 per cent. Taken together with the existence of slit losses, this more than offsets the slight gain in efficency at the grating obtained by using the focal modifiers. *There are therefore no circumstances under which it makes sense to use the focal modifier lenses.*