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Chapter 1

Introduction

1.1 The subject of this Manual

This manual is intended to provide information primarily to observers and support astronomers, but also to potential users of the Intermediate Dispersion Spectrograph (IDS) on the Isaac Newton Telescope, using a Charge Coupled Device (CCD) as a detector. It describes how to use the IDS and the CCD and includes a comparison with the other type of detector available with the IDS: the Image Photon Counting System (IPCS). Some overlap with the manual for spectroscopy with the IPCS on the INT is therefore unavoidable.

This manual is intended to replace manual # VII *Spectroscopy with the CCD on the INT* (P.R. Jorden and W.L. Lupton, 1984), and includes extracts from manual # XVIII *A User Guide to the JKT CCD Camera* (R.W. Argyle et al. 1988), manual # VI *Spectroscopy with the IPCS on the INT – Cook book* (C.R. Jenkins 1986) and *Observer's Guide* (S.W. Unger et al. 1988).

1.2 What to read before this

For general information about the other telescopes, instruments and detectors of the Isaac Newton Group of Telescopes at the Observatorio del Roque de los Muchachos on the island of La Palma, please consult the Observer's Guide.

Astronomers should first read that Guide because it explains how to apply for observing time, how to communicate with and travel to the observatory and it shows what documentation is available and where. The Guide also directs you to the appropriate scientific or technical specialist at Herstmonceux or La Palma for up-to-date information and advice.

The RGO newsletter *Gemini* (or the PATT Newsletter) should be read for the latest information about the Observatory, and about documentation releases.

1.3 Contents of this Manual

A colour-coding has been used in this Manual, pink pages being those containing only essential information suitable for experienced observers.

Chapter 2 describes briefly a CCD detector, the CCDs available with the IDS at the INT and their performance.

Chapter 3 describes the IDS, including the cross-disperser option, and the acquisition and guiding (A&G) box.

Chapter 4 describes a typical observation with the IDS + CCD from set-up to finish, going through calibrations and tests required. Sections 4.4 and 4.5 (pink pages) contain the Quick Reference Cards which outline a typical observing run giving brief details only. They are intended for experienced observers. The current version of the Cards is in the Telescope Control Room, together with other "Latest Info".

Chapter 5 describes ADAM, the command language which is used to interact with the instrument-control software for data entry and checking, prompting and some basic data inspection.

Flux standards are discussed in Appendix A, first steps in data reduction are suggested in Appendix B, information on calibration arcs (mostly provided by Ed Zwiderwijk) is given in Appendix C and filters and masks information are summarized in Appendix D.

Many people have contributed to this manual. The authors want to thank very specially the team at La Palma, in particular David King, Chris Mayer, David Carter and Anne Charles. Thanks are also due to the Support Astronomers group at Herstmonceux for useful suggestions.

Chapter 2

CCD Detectors

2.1 Introduction

The two types of electronic detector available with the IDS are the Image Photon Counting System (IPCS), and a range of Charge Coupled Devices (CCDs). If you are reading this manual you have already decided that the CCD is best suited for your particular observation. The Observer's Guide has a thorough discussion comparing both types of electronic detector available with the IDS (CCD and IPCS); see also Gemini # 21. We will include here the relevant conclusions for a CCD user. The CCD is described in Sections 2.2 and 2.3. (If you are interested in the IPCS, see the "IPCS Cook Book" and the "IDS + IPCS" Manual, currently in preparation).

2.2 Overview

A CCD is a 2-dimensional electronic detector. It has enormous attractions for astronomers: linearity, with dynamic ranges of 10000 being realized; photometric accuracy, better than 1 per cent; speed, with quantum efficiencies of up to 80 per cent; wide wavelength response, some devices being usable from the near UV ($<$ 300 nm) to the near IR ($>$ 1 μm) and digital output, with data readily available in the computer. In addition, it is mechanically stable, extremely tough and difficult to damage by excess illumination. The main disadvantages of CCDs (as available at present at the INT) are the small size as compared to photographic plates or an IPCS, and the presence of readout noise, which renders it less suitable than an IPCS for the study of very faint or rapidly varying objects.

This section is a brief description of a CCD. Some useful references for further reading are:

ESO-OHP workshop on the Optimization of the Use of CCD detectors

in astronomy, eds. Baluteau, J.P. & D'Odorico, S., 1986

Wall, J.V. & Laing, R.A. *User's Guide to the prime focus CCD camera on the INT*

Argyle, R.W., Mayer, C.J., Pike, C.D. & Jorden, P.R.
User Guide to the JKT CCD camera, 1988.

Jorden, P.R. *Basic parameters of CCDs in use at La Palma,*
La Palma Technical Note 55, revised September 1988

2.3 General description

A CCD is a silicon based semiconductor arranged as an array of photosensitive elements, each one of which generates photoelectrons and stores them (to use the now familiar figure of speech) as a small 'bucket' of charge. Each pixel is typically 20 to 30 μm square. CCDs in use as astronomical detectors for the past five years have about 200,000 pixels, usually arranged in a format of about 500 rows by 400 columns, and the active area is thus about 1 square centimetre.

When requested, the elements form a bucket brigade; each row of charges is passed from element to element, a process which is known as clocking, down the columns and horizontally along the final row. The value in each pixel is measured in turn and recorded digitally. To ensure that only positive numbers result from this analogue to digital conversion process a fixed offset known as the bias level is introduced. The charge-transfer process is essentially noise-free and almost all of the noise contributed to the signal by the CCD is from the output stage, where the charge content of each bucket is measured. This is called the readout noise.

The dark current of CCDs means that they must be cooled to cryogenic temperatures for use as astronomical detectors. At room temperatures, the dark signal is such that most CCDs would saturate in < 1 second. Cooling via temperature-controlled liquid-nitrogen dewars or by closed-cycle refrigeration provides a crucial reduction in dark current. The mobility of electrons is somewhat impaired by cooling, so that a compromise is required to maintain adequate charge-transfer efficiency. The optimum temperature is about 150 K.

2.4 Design

CCDs require electronics to generate electrode biasses, clocking waveforms, low-noise amplification of weak signals, A/D conversion, buffering, and digital storage. They also require temperature-controlled environments mountable at different telescope foci for direct imaging, and at spectrograph foci for use as spectroscopic detectors. The details of how operational systems meet these demands differ, but the major elements are similar.

The cryostat or dewar provides the cooled environment for the CCD. A liquid-nitrogen cryostat designed at RGO can be used in either downward or upward-looking modes, for example in direct imaging at prime or Cassegrain foci. It has a hold time of some 12 hours so that it only has to be filled once a night. The CCD itself is mounted behind an anti-reflection coated quartz window, on a copper block with which it makes good thermal contact and which has a temperature sensor attached. Resistive heating controlled by a feedback loop maintains the CCD at the optimum operating temperature of 150 K to within $\pm$0.05 K. A preamplifier is mounted on the cryostat.

The main functions of the electronics needed to drive the CCDs are: analogue signal sampling and CCD control, digitisation of data, telemetry of system voltages, control interfaces and data links to the instrument computer. The systems may be reprogrammed in order to use a wide variety of different chip types or operating modes. Windowed readout of the chip can be used to minimise readout time or data storage. On-chip binning (available for most chips) can be used to increase signal to noise at the expense of spatial resolution.

2.5 CCD systems on the INT

The CCD systems on the INT use either an RCA type SID501 chip, or a GEC P8603, dye coated for improved blue response. Table 2.1 summarises important general parameters of the two types of CCD chip available, and has been taken with some modification from La Palma Technical Note 55, which describes the CCD systems available in rather more detail.

It can be seen that the two chips complement each other well. The RCA SID501 is larger and has a higher efficiency at most wavelengths, and so is better suited for those imaging applications requiring a large field and deep, broad-band exposures. The GEC P8603 has a much lower readout noise and so will be better suited for most spectroscopic applications. The principal limitation of the RCA chip for spectroscopy is that it is thinned and hence gives rise to very large amplitude interference fringes. **Hence, only the GEC chip is offered with the IDS.**

2.5.1 Performance

Efficiency

A major advantage of CCDs is their high efficiency. The nominal wavelength response for the two types of CCD currently in use on La Palma is shown in Figure 2.1. The RCA SID501 has a peak efficiency of about 75 per cent, whilst the GEC P8603 has a peak efficiency of about 55 per cent. Both chips have a useful sensitivity over most of the optical/near IR spectrum. Note however that although the useful response of the GEC P8603 extends down to the atmospheric cutoff at about 3000 Å, the response of the RCA SID501 cuts off sharply below about 3500 Å. Our measurements however indicate that the blue performance of the RCA is significantly worse than this, and is completely useless in the U band. The GEC response is close to that shown.

Noise level

The read out noise for the CCD chips used on La Palma is given in Table 2.1. This is typically 5-10 electrons per pixel for the GEC P8603 and about 60 electrons per pixel for the RCA SID501

Table 2.1: CCD parameters

Chip	GEC P8603	RCA SID501
Pixel size (μm)	22×22	30×30
Format (pixels)	385×578	320×512
Format (mm)	8.5×12.7	9.6×15.4
Readout frame (pixels)	400×590	350×512
Readout time (seconds)	$\sim$25	$\sim$10
Electrons per ADU	$\sim$1	$\sim$4
Saturation (ADU)	>60000	>60000
R.Q.E. (per cent)		
Peak	55	75
400 nm	15	40
800 nm	40	60
Noise:		
Readout noise	5–10	$\sim$60
Cosmic ray events (events frame^{-1} min^{-1})	1–2	$\sim$6
Dark count (ADUs pixel^{-1} hour^{-1})	<1	<1

ADU=Analogue-Digital conversion Units.
R.Q.E.=Responsive Quantum Efficiency.

Figure 2.1: Responsive quantum efficiency of the CCD chips available in the INT

Cosmic ray events become important for longer exposures. During an exposure cosmic rays hit the CCD. When a pixel is hit, its charge content is vastly increased and the resulting 'spike' in the image needs to be removed during the data reduction stage. This can be done either by numerical filtering techniques using the fact that the appearance of a cosmic ray event is quite distinct from that of an astronomical object, or by combining multiple exposures of the same object. The former process is likely to be interactive and (therefore slow) and a "patch" with information in the strike zone is irretrievably lost. The latter is recommended.

Saturation level and dynamic range

The peak capacity of a CCD pixel is typically 200,000 electrons, and CCDs are demonstrably linear devices up to within a factor of two of this limit. When the limit is exceeded, the arrival of more photons continues to create further photoelectrons, which then spread out along the column of the CCD.

In addition to saturating the chip, it is possible to saturate the analogue to digital converter. Although the maximum digitised count is 65,535 (2^{16}-1), it is advisable to keep the number of counts below about 35,000 to avoid non-linear effects.

Together with readout noise, the saturation level defines the dynamic range of a CCD, crudely, as (saturation level)/(readout noise).

Charge transfer efficiency

At low light levels the charge transfer is sometimes imperfect and the bucket brigade spills some electrons along the way during read-out. This results in slightly deformed images, showing a trailing along the rows and/or columns of the CCD. Faint asymmetric wings may be generated around bright emission lines. To improve the performance one can preflash the chip by pre-illumination with a fixed amount of light. This is, of course, undesirable because it adds shot noise to the data. Although all the chips currently in use on La Palma have good charge-transfer characteristics and are said by the manufacturers not to require preflash, the charge-transfer is not perfect. Therefore we recommend that users consult their support astronomer over whether a preflash is needed.

Cosmetic defects

Cosmetic defects can come in many varieties, and vary from chip to chip. Dark columns, areas where charge-transfer is inhibited unless a threshold of electrons is present, can be dealt with effectively by pre-flashing. Defective areas such as bad columns, bad pixels or hot pixels cannot be cured. Each chip has its "fingerprint" of cosmetic defects and care should be taken to avoid the worst affected areas when positioning an object on the chip. Multiple exposures in which the object of interest is shifted to a different location on the chip between exposures can be of great help to obtain clean images.

Other factors in addition to the required signal to noise ratio which need to be taken into account when choosing a detector are:

Detector size

For certain types of experiment, it may be important to note that the IPCS is a much larger detector than any of the CCDs currently available on the INT. For spectroscopic observations, the INT IPCS provides 2044 pixels along the dispersion direction, each about 15 μm in size. The GEC CCD provides 578 pixels along the dispersion direction, each 22μm in size. This means that for a fixed wavelength resolution, the IPCS provides almost 2.5 times the wavelength coverage. The usefulness of this multiplex advantage depends very much on the type of experiment being performed. For an experiment where wavelength coverage is important, it might mean that the IPCS is the preferred detector, even though the integration time to reach the desired signal to noise ratio in each resolution element is 2-3 times longer. A new generation of CCDs with 1000^2 to 2000^2 pixels is becoming available for astronomical observations and we hope to offer it on the INT from 1990.

Real time data display

The data cannot be inspected in real time with the CCD. This is a serious drawback when doing surveys, because one cannot terminate an exposure on the basis of the actual signal to noise ratio reached, as is the case with the IPCS.

Saturation

The exposure time for bright objects could be limited by saturation.

Cosmic ray events

These are an important source of additional noise on a CCD, limiting in practice the exposure time. Cosmic rays which strike the detector produce bright and narrow noise spikes in the signal. The effect on the data depends exactly on where on the detector the event occurs. The best way to deal with cosmic rays is to break long exposures into several shorter ones. This has the major disadvantage of increasing the total readout noise. If the total number of events is small they can usually be succesfully removed by software.

2.6 Exposure times

Once the signal to noise ratio required for the observation to be successful has been defined, you want to estimate the integration time needed to achieve it. Here we outline how to perform this calculation.

The noise level for a typical astronomical observation will consist of three components. The first component is signal independent noise arising from the detector itself (readout noise). Secondly, we have shot noise in the signal from the object being observed. This follows a Poisson distribution, so its variance is equal to the signal level. Finally, we also have shot noise in any background signal (particularly the sky background and preflash). Adding the noise terms in quadrature, the signal to noise ratio (SNR) is given by:

$$SNR = \frac{E \times N_{obj} \times t}{\sqrt{(E \times N_{obj} \times t) + (E \times N_{back} \times t) + \sigma^2}} \tag{2.1}$$

E	=	Responsive quantum efficiency of the detector
N_{obj}	=	Number of photons per resolution element per second incident on detector from object
N_{back}	=	Number of photons per resolution element per second incident on detector from background (e.g. sky)
t	=	Integration time
σ	=	Readout noise

The signal to noise ratio obtained therefore depends on both the efficiency of the detector and the level of detector noise.

Table 2.2 gives estimates of the efficiency of the GEC CCD at a number of wavelengths from Figure 2.1.

Table 2.2: CCD efficiency

Wavelength (Å)	Detector efficiency (%) GEC P8603
3500	12
4000	15
4500	15
5000	24
5500	35
6000	42
6500	50
7000	50
7500	51
8000	45
8500	33
9000	22
9500	10

The detector noise of a CCD is dominated by the readout noise, which is 5–10 electrons per pixel for the coated GEC P8603 (Table 2.1). Note however that the number we really need is the readout noise per resolution element, not the readout noise per pixel. The readout noise per resolution element depends on two factors:

- How many CCD pixels are there in a resolution element ? In slit spectroscopy of a point object, the emission might easily be extended for several pixels along the slit, and we will need to bin these up in order to obtain a spectrum. Similarly, for an experiment to detect a well-resolved emission line, it may be possible to bin up several pixels in the dispersion direction into one resolution element. Note that according to sampling theory, a resolution element must always be at least two pixels in each direction. In order to obtain the effective readout noise per resolution element, the readout noise per pixel must be multiplied by the square root of the number of pixels in a resolution element.
- How many separate CCD exposures are being combined? The target object may be so faint that a very long integration time is necessary to obtain the desired signal level. Figures 2.3 to 2.5 can be used to estimate the total integration time required. If the total integration time is greater than about 1/2 an hour, it will be necessary to split the observation into a number of shorter exposures. Each CCD exposure adds in more readout noise, resulting in the effective detector noise being equal to the readout noise per exposure times the square root of the number of exposures.

A first relatively straightforward but important case is where the noise level is dominated by shot noise on the sky background (sky limited observations). This is usually the case for low resolution spectroscopy or imaging observations. Typical values for the sky brightness on La Palma in a variety of wavebands are given in the Observer's Guide. As far as signal to noise is concerned, the most effective detector for sky limited observations is simply the most efficient.

We now consider the case where the sky background can be neglected, normally the case for high resolution spectroscopy or bright objects. As we noted above, observations at high signal levels, where we might expect a high signal to noise ratio, will be best suited for the CCD, whereas observations at low signal levels, and low signal to noise ratio, will be best suited for the IPCS. The basic message here is that if you intend to take short exposures of fairly bright objects, you should probably use the CCD, whereas if you expect to observe the same object all night to obtain adequate signal to noise ratio (S/N $<$ 30), you should probably be using the IPCS.

As discussed above, the signal to noise ratio obtained from an observation depends on two factors: the level of detector noise, and the number of photons detected in each resolution element. In what follows we present the data necessary to estimate the number of photons incident on the detector in each resolution element.

For a system with no light losses, it is straightforward to show that the number of photons incident in each resolution element is given by:

$$N = 15092 \times A \times F \times f \times \frac{\delta\lambda}{\lambda} \qquad (2.2)$$

N = Photon flux at the detector per resolution element (photons $\sec^{-1}$)
A = Geometric aperture of the INT telescope (m^2)
= 4.41
F = Monochromatic flux density of object (mJy)
If you like to work in magnitudes you should use the fact that
an object with a magnitude of m_{AB} = 15 has a flux density of 3.6 mJy.
f = Fraction of total flux density of object in each spatial resolution element.
Note that for slit spectroscopy, the spatial resolution perpendicular to the direction of the slit is set by the slitwidth. For many observations, the slitwidth will be comparable to the size of the seeing disc, and so even for sources which are intrinsically unresolved, a significant fraction of the light will not enter the spectrograph.
$\delta\lambda$ = Observing bandpass (Å). For imaging observations, this is the FWHM of the filter used. For spectroscopy, it is equal to the wavelength resolution of the observations.
λ = Observing wavelength (Å)

Unfortunately, only a small fraction of these photons are actually detected, perhaps 1 per cent! This low efficiency is due to a number of factors, discussed in what follows.

2.6.1 Atmospheric extinction

La Palma Technical Note 31 (King, 1984) discusses the atmospheric extinction on La Palma in some detail. Briefly, it is possible to separate the extinction into a wavelength dependent component, due to Rayleigh scattering by air molecules and absorption by ozone, and a component due to dust scattering which is to some extent wavelength independent because large dust particles dominate the size distribution. The wavelength dependent component is plotted as a function of wavelength and airmass in Figure 2.2. Table 2.3 gives the airmass as a function of zenith distance. It can be seen that this component of the atmospheric extinction is much more important in the blue than in the red, varying from 3.7 magnitudes per unit airmass at 3000 Å to 0.007 magnitudes per unit airmass at 10000 Å.

The extinction due to dust scattering varies from night to night, but is usually less than a few tenths of a magnitude per unit airmass. The total vertical extinction in the V band (i.e. the sum of the wavelength independent and wavelength dependent components) is measured each night by the Carlsberg Automatic Meridian Circle, and users with access to STARLINK may examine these results in the file **RGVAD::SYS$SYSDEVICE:[LPINFO.EXTINCTION]CAMCEXT.DAT.**. These data may be used to estimate the dust extinction on any particular night. Obviously, the use of a plane-parallel azimuth-independent geometry (the sec z law) is less accurate for dust extinction than for air.

2.6.2 Telescope efficiency

Light is lost at each reflection from an aluminised telescope mirror. It is difficult to quantify this precisely, since the reflectivity of the mirror degrades with time, but a value of 85 per cent for the reflectivity would be a reasonable estimate.

Figure 2.2: Theoretical atmospheric extinction on La Palma as a function of wavelength and airmass

Table 2.3: Airmass as a function of zenith distance

Zenith distance (degrees) œ[œœOu	Airmass
0	1.000
20	1.064
40	1.304
50	1.553
55	1.740
60	1.995
65	2.357

2.6.3 Spectrograph efficiency

The efficiency of the INT IDS is best considered as the product of three components; collimator, grating and camera. The efficiencies of the 3 collimators available are plotted in Figure 2.3, and the efficiencies of the various gratings are plotted in Figure 2.4. The efficiencies of the 2 cameras are discussed in Chapter 3.

2.6.4 Filters

Filters will be used in spectroscopic observations, when for example it is necessary to reject light from unwanted orders or spectral regions.

Figure 2.5 shows the wavelength dependence of transmission of the Schott glass filters used on La Palma.

2.6.5 Detector efficiency

The efficiency of the two types of CCD used on La Palma is shown in Figure 2.1.

Figure 2.3: Efficiency curves for the IDS collimators

Figure 2.4: Grating efficiencies as a function of wavelength

Figure 2.4: (Cont.)

Figure 2.4: (Cont.)

Figure 2.5: Transmittance of Schott glass filters as a function of wavelength

Chapter 3

The Intermediate Dispersion Spectrograph

3.1 Overview

The Intermediate Dispersion Spectrograph (IDS) is the principal common-user instrument at the Cassegrain focus of the INT. The IDS design is based on the principle of a folded-input, flat-bed instrument. The "straight through" position is occupied by the Faint Object Spectrograph (FOS-1; see the Observer's Guide). Figure 3.1 shows the overall optical layout; selection of either IDS or FOS-1 operation is determined by manual movement of a single optical element, the folding prism, so that both spectrographs, and indeed both cameras of the IDS, albeit with different detectors, can be used consecutively during the same night. Facilities for acquisition and guiding, such as calibration and comparison lamps, above-slit neutral-density and colour filters, the autoguider and a TV camera, are all located in a separate A&G unit to which the spectrograph is attached (Section 3.2). Dekker masks, slit assembly and below-slit filters are within the main body of the spectrograph itself.

3.1.1 Design

The layout of the IDS spectrograph is shown in Figure 3.1. The following components can be discerned:

- **Slit and dekker unit.** The same slit and dekker unit is shared by the IDS and FOS-1. The maximum slit length is 44.3 mm (4 arcmin); the slit width is variable from 40 μm (0.216 arcsec) to 1.745 mm (9.43 arcsec) in steps of 5 μm (0.027 arcsec). The entire slit assembly can be removed, if required. Dekker plates are interchangeable in sets; each individual set consisting of 8 apertures and a clear position. Several standard dekkers, incorporating single slots, pairs of slots, a "comb", and a coronographic set-up, are always available.

Figure 3.1: The Intermediate Dispersion Spectrograph

A multislit unit is also available. This consists of ten parallel slitlets, each 16″ long with a 7″ gap between each pair and with a fixed width of 270 μm (1.46″ at the Cassegrain focus). Each slit can be moved perpendicular to the slit orientation by up to 1.6′ in either direction. With FOS-1 a useful field of 4′ by 3′ can be covered, whereas the IDS has a smaller field of 4′ by 1′. A program is available for finding the optimum arrangement and typically one needs 20 or 30 objects in the field to make use of all 10 slits. Astrometry to within 0.3″ is needed to use the unit effectively. There is only one module that has to be preset using a Coradograph xy table in the INT building. Clusters of objects spread over less than 1′ are less likely to benefit as they are too small. To install the multislit assembly, the conventional Cass cluster slit assembly is replaced by a similar one which holds the multislit module or a long-slit equivalent. This instrument change requires lowering the IDS and is a daytime operation. The long slit module allows observations to continue while the multislit module is being preset with the Coradograph for a new field. The device should not be regarded as a general purpose multiobject coupler but rather as a special purpose addition to the INT Cassegrain cluster instrumentation. See *Using the multislit unit at the INT Cassegrain focus (R. Ellis et al. 1986)* for more information.

- **Filter slides.** In addition to the above-slit filter positions in the A&G unit, there are 3 filter positions available below the slit for both colour and ND filters. One of these positions is always clear. Five colour filters are currently available: UG11, BG18, BG24 and BG38, measuring 19 mm $\times$ 60 mm $\times$ 2 mm and made from Schott glass. The wavelength dependence of the transmission of these filters is shown in figures 2.5 and 2.6. The copper sulphate filter cuts out the part of the spectrum from 600 – 650 nm redwards and is usually employed to block the red leak of the UG11 filter or to remove the FOS-1 first order. The neutral density filters below the slit provide a choice of ND = 0.5, 1.0 and 1.5. Note that the use of filters below the slit makes it necessary to refocus the spectrograph.

- **Collimator.** The collimator is of 1275 mm focal length, giving a collimated beam with a diameter of 85 mm. There is a choice of three different collimators, with different coatings for maximum reflectivity in the wavelength range of interest. The efficiency of the collimators as a function of wavelength is shown in Figure 2.3. The collimators can be exchanged during the night by the support staff. The collimator is mounted on a remotely-driven sliding carriage, making it possible to focus the spectrograph under computer control.

- **Cameras.** Two cameras are available with the Intermediate Dispersion Spectrograph. Both are of the folded short-Schmidt type, described in detail by Wynne *(M. N. R. A. S.,***180***, 485, 1977)*. The focal lengths of the two cameras are 235 mm and 500 mm.

  Along the direction of the slit (i.e. perpendicular to the dispersion direction), the focal lengths of 235 and 500 mm imply slit to detector reduction factors of 5.43 and 2.55 respectively, and hence scales at the detector of 29.4 and 13.8 arcsec mm^{-1}.

  Along the dispersion direction, the slit to detector reduction factor is more complicated, since it depends on the grating angle. Tables 3.1 and 3.2 give the slit width in arcsec which projects to 30 μm at the detector, when each grating is used at its central wavelength.

Tables 3.1 and 3.2 also list the dispersion provided by each grating and camera combination. It can be seen that a wide range of dispersions is available, from 7 Å mm^{-1} to 270 Å mm^{-1}.

- **Gratings.** The gratings have a ruled area of 102 mm $\times$ 128 mm. A wide selection is available, and some of the important characteristics of each grating are summarised in Tables 3.1 and 3.2. The efficiency of the gratings as a function of wavelength is shown in Figure 2.4. Grating changes can be made during the night by support staff.

- **Cross-disperser.** A transmission grism, R60B with 60 lines mm^{-1} and blazed at 4800 Å, can be inserted into the collimated beam in the 235 mm camera to provide a cross-dispersion option. This is used in conjunction with an R150 echelle grating, which is blazed at 2.7 μm. The FOS-1 dekker mask is used to limit the slitlength to 25 arcsec in order to avoid order confusion. The wavelength range for the CCD and dispersion provided by this grating in each order, for a grating angle of 60°, are summarised in Table 3.3. There are no gaps in wavelength coverage with the IPCS. The CCD is not normally considered the detector best suited to use with the cross-disperser, because part of the wavelength coverage is lost between the orders due to the physical size of the chip. However, it is usually possible to adjust the grating angle in the range 59.5°- 60.5° so as to ensure that all interesting spectral features are placed in the chip. Besides the advantages typical of CCDs, the combination of GEC chip and cross-disperser, seems to have a higher sensitivity than the combination of IPCS and cross-disperser. 13 counts/sec/Å were obtained for a m_V=11.9 star at an airmass of 1.32 with the CCD. 1 count/sec/Å therefore, can be expected for a m_V=14.8 at an airmass of 1.0. This count rate corresponds to a m_V=13.9 with the IPCS, but of course the IPCS's quantum efficiency is much lower at 5500 Å than that of the CCD. The central wavelength and wavelength coverage in Å can be obtained for each order n as

$$\Delta\lambda = 3586/n$$

and

$$\lambda_c = \frac{[26364 - 2166.5 * (Angle - 60^\circ)]}{n}$$

Table 3.1: Characteristics of the IDS gratings with the 235 mm camera

Name[1]	Origin[2]	Ruling (lines mm^{-1})	Blaze (Å)	Efficiency[3] (%)	Central wavelength (Å)	Dispersion[4] (Å mm^{-1})	Entrance slit for 30 μm at detector (arcsec)
R150V	B+L	150	5250	66	5500	271.3	1.03
R300V	NPL	300	5460	72	5500	138.5	1.05
R400B	B+L	400	3900	50	4000	104.5	1.06
R400V	B+L	400	5100	72	5500	104.5	1.08
R400R	B+L	400	7250	59	8000	104.4	1.11
R600R	B+L	600	6700	65	7000	69.8	1.16
R600IR	B+L	600	10000	70	8500	70.2	1.19
R632V	NPL	632	5460	72	5500	66.5	1.11
R831R	B+L	831	7500	65	8000	50.7	1.27
R900V	B+L	900	5100	69	5000	46.4	1.17
R1200U	J-Y	1200	3500	68	3500	35.3	1.15
R1200B	J-Y	1200	4000	76	3500	35.3	1.15
R1200Y	B+L	1200	6000	68	6500	35.2	1.33
R1200R	B+L	1200	8000	66	7000[4]	34.8	1.37
H1800V	PTR/NPL	1800	5300	64	5000[5,6]	23.2	1.40
H2400B	J-Y	2400	4000	60	3500[5,7]	17.5	1.37

1) Prefix R for ruled grating; prefix H for holographic grating.
2) Key: NPL = National Physical Laboratory; B+L = Bausch and Lomb;
J-Y = Jobin-Yvon; PTR/NPL = PTR replica from NPL master.
3) Absolute efficiency values measured at RGO.
4) At low and intermediate dispersions the dispersion changes little with central wavelength.
5) Near maximum useful angle of incidence
6) Optimized for 5000-7000 Å.
7) Optimized for 3500-5500 Å.

Table 3.2: Characteristics of the IDS gratings with the 500 mm camera

Name[1]	Origin[2]	Ruling (lines mm^{-1})	Blaze (Å)	Efficiency[3] (%)	Central wavelength (Å)	Dispersion[4] (Å mm^{-1})	Entrance slit for 30 μm at detector (arcsec)
R150V	B+L	150	5250	66	5500	132.2	0.51
R300V	NPL	300	5460	72	5500	66.1	0.52
R400B	B+L	400	3900	50	4000	49.6	0.52
R400V	B+L	400	5100	72	5500	49.7	0.52
R400R	B+L	400	7250	59	8000	49.9	0.54
R600R	B+L	600	6700	65	7000	33.3	0.56
R600IR	B+L	600	10000	70	8500	33.4	0.58
R632V	NPL	632	5460	72	5000	31.6	0.54
R831R	B+L	831	7500	65	8000	23.9	0.59
R900V	B+L	900	5100	69	5000	22.1	0.56
R1200U	J-Y	1200	3500	68	3500	16.7	0.55
R1200B	J-Y	1200	4000	76	3500	16.7	0.55
R1200Y	B+L	1200	6000	68	6500	16.4	0.61
R1200R	B+L	1200	8000	66	8000	15.5	0.63
H1800V	PTR/NPL	1800	5300	64	5500[6]	10.5	0.65
					7000	9.8	0.73
H2400B	J-Y	2400	4000	60	3500[5,7]	8.1	0.62
					6000	6.8	0.82

1) Prefix R for ruled grating; prefix H for holographic grating.
2) Key: NPL = National Physical Laboratory; B+L = Bausch and Lomb;
J-Y = Jobin-Yvon; PTR/NPL = PTR replica from NPL master.
3) Absolute efficiency values measured at RGO.
4) At low and intermediate dispersions the dispersion changes little with central wavelength.
5) Near maximum useful angle of incidence
6) Optimized for 5000-7000 Å.
7) Optimized for 3500-5500 Å.

Table 3.3: Characteristics of the IDS R150 echelle grating

Order	Central wavelength (Å)	Wavelength range (Å)	Dispersion (Å mm^{-1})
3	8790	8190 - 9385	94.0
4	6590	6145 - 7035	70.5
5	5275	4920 - 5630	56.4
6	4395	4100 - 4690	47.0
7	3766	3510 - 4020	40.3
8	3295	3070 - 3520	35.2
9	2930	up to 3130	31.3

- **Detectors.** The IDS can be used with two detectors: the IPCS or a coated GEC P8603 CCD. Changing the detector on a particular camera can only be carried out during the day. However, it is possible to have a CCD set up on one camera and the IPCS on the other, and operate the two systems consecutively during the same night. Switching from one camera to the other only requires the grating to be rotated by 180° around the optical axis (or exchanged), and the control software to be reinitialized. Note that if you only specify a detector to be on one camera in your proposal, you cannot guarantee what will be on the other (e.g. it might be in use on another telescope). If you need both cameras, you have to specify that well before your run.

3.1.2 Performance

Wavelength range and resolution

Table 3.4 summarises the wavelength range and resolution for the IDS gratings using a coated GEC CCD and either the 235 mm or the 500 mm cameras. With the exception of the 1800 and 2400 lines mm^{-1} gratings, the wavelength coverage does not significantly vary with the central wavelength.

The tables give for each configuration the wavelength range, the dispersion in Å $pixel^{-1}$, and the slit width projecting to one pixel at the detector. For proper sampling, the wavelength resolution cannot be less than about 2 pixels. To match the slit to the resolution ot the spectrograph, a slit width should be used which projects to about 2 pixels at the detector. If a wider slit is used to increase the total light collected by the instrument, this will degrade the wavelength resolution. This might be a good strategy in bad seeing conditions or for extended objects.

One point worth noting is that if a grating were to be mounted with the wrong orientation, (i.e. the blaze directed towards the other camera) it would result in a dramatic decrease of throughput. The dispersion will be affected too, and, in fact, a resolution improvement of about 20% can be obtained at high anamorphic magnification, but only at the cost of a drastic loss of

Table 3.4: IDS Wavelength range and resolution

		GEC CCD 578 22 μm pixels					
		235 mm camera			500 mm camera		
Grating	λ_c	(1)	(2)	(3)	(1)	(2)	(3)
R150V	5500	3430	5.97	0.76	1680	2.91	0.37
R300V	5500	1760	3.05	0.77	840	1.45	0.38
R400B	4000	1320	2.30	0.78	625	1.09	0.37
R400V	5500	1320	2.30	0.79	625	1.09	0.38
R400R	8000	1320	2.30	0.81	630	1.10	0.40
R600R	7000	880	1.54	0.85	420	0.73	0.41
R600IR	8500	885	1.54	0.87	420	0.73	0.43
R632V	5500	840	1.46	0.81	400	0.70	0.40
R831R	8000	640	1.12	0.93	300	0.53	0.43
R900V	5000	585	1.02	0.86	280	0.49	0.41
R1200U	3500	445	0.78	0.84	210	0.37	0.40
R1200B	4000	445	0.78	0.84	210	0.37	0.40
R1200Y	6500	445	0.77	0.98	205	0.36	0.45
R1200R	7000	440	0.77	1.00	195	0.34	0.46
H1800V	5500	290	0.51	1.03	130	0.23	0.48
	7000				120	0.22	0.54
H2400B	3500	220	0.38	1.00	100	0.18	0.45
	6000				85	0.15	0.60

1) Wavelength range (Å)
2) Dispersion (Å pixel^{-1})
3) Slit width projecting to 1 detector pixel (arcsec)

efficiency (see J.V. Wall 1984, Gemini # 12).

Throughput

The efficiency of the cameras can be split into two components, one due to the geometry of the cameras (e.g. size of the central obstruction) and one due to losses at each coated surface. For small grating angles, the geometric efficiencies of the 235 mm and 500 mm cameras are about 67 % and 73 % respectively. At large grating angles (greater than about 44° and 60° for the 235 and 500 mm cameras respectively), the geometric efficiency drops off rapidly due to overfilling of the grating. This will for example occur with the 2400B grating when used in the red.

Each camera contains two aluminium mirrors, with a reflectivity of about 85 %, and four air/glass surfaces with single layer anti-reflection magnesium fluoride coating, each of which has a reflectivity of about 2 % at 5500 Å. We therefore expect the 235 mm and 500 mm cameras to have total effective efficiencies of 45 % and 49 % respectively.

Performance of cross-dispersion option

The wavelength coverage provided by the cross dispersion option depends on the physical size of the detector; it is given in Table 3.3. The current generation of CCD detectors are too small to cover the wavelength range at once, though it is usually possible to cover most important emission lines by a careful choice of grating angle.

The measured efficiency of echelle and the cross-disperser is discussed in Section 3.1.1.

3.1.3 Calibration facilities

Comparison lamps for the IDS are mounted in the INT Cassegrain A&G box, which are described in some detail in the next Section (and Appendix C).

3.2 The Cassegrain acquisition and guiding (A&G) box

At the rear of the INT primary mirror cell is the Cassegrain turntable which can be rotated by 365 degrees, and onto which the A&G unit is mounted. The Cassegrain A&G Unit of the INT has been designed primarily for use with the IDS and FOS-1. Nevertheless, the overall philosophy of the design has been to incorporate a range of facilities which would be required by most instruments operating at the Cassegrain focus. The full field is 20 arcmin in diameter, but the comparison lamps and filters are only useful over a more restricted field of 4 arcmin, matching that of the IDS.

The following functions are provided:

- **Acquisition:** Figure 3.2 shows the details of the optical system for viewing the acquisition field. A Westinghouse extended S20 TV camera views a nominal 1.8 × 1.8 arcmin element of the 20 arcmin diameter unvignetted Cassegrain field (on- or off- axis). The TV display includes labels giving orientation and scale.

  A useful facility available is the option to store the TV images, so as to take advantage of periods of exceptionally good seeing to record, for later use, high spatial resolution images of the objects under investigation; the images (called “TV archive images” can also serve as a reference to show the slit position for extended objects. At the user’s request, they can be obtained by the Telescope Operator.

  A filter wheel is available for the TV camera allowing up to four circular filters to be loaded. These filters are not immediately accessible, as it is envisaged that most users would not require them to be replaced. The filters currently available are blue (BG28), green (BG38), red (RG630) and clear (UBK7). (See Figure 2.5).

Figure 3.2: The optical system for viewing the acquisition field at the Cassegrain focus of the INT

- **Slit viewing.** A simple movement of the flip mirror allows viewing of the light reflected from the slit jaws using the acquisition TV. This facility gives visual confirmation of the position of the target on the entrance aperture of the instrument, as well as an approximate estimate of the seeing profile.

- **Autoguider.** An autoguider is available which allows offset guiding using stars anywhere in a 90 arcmin^2 field. The area available for guide stars is shown in Figure 3.3. Guide stars should have magnitudes in the range $7 < m_v < 13$.

  For blind setting of the telescope, for locating the spectrograph slit relative to a guide star, or for controlling small telescope offsets to make a spectroscopic map of an extended object, guide stars should be selected in advance of the observing run using Figure 3.3. If this is done, and the (α, δ) of the guide stars is known, then it is possible to save considerable amounts of observing time. Alternatively, an overlay showing the IDS slit and the area within which guide stars may be selected can be superimposed on the TV image of the finder field. A guide star can then be selected visually, and the A&G Unit TV and/or autoguider probes can be directed to that position. Care must be taken to avoid selecting a guide star so positioned in the field that the autoguider probe obstructs the on-axis star-beam. The Telescope Operator will normally set up the autoguider.

- **Comparison lamps.** The A&G Unit includes reference sources for calibrating the wavelength scale and the photometric response of the attached instrument. The lamps are housed in an integrating sphere which can contain up to two hollow-cathode lamps and one tungsten lamp; more than one source at a time can illuminate the slit. Illumination of the slit by the comparison lamps is achieved by movement of a dedicated mirror.

  The standard set-up consists of a tungsten lamp as continuum source, and copper-argon and copper-neon discharge lamps for wavelength calibration. A further selection of the following discharge lamps is offered: Th-Ar, deuterium, Fe-Ne, Fe-Ar, Al/Ca/Mg-Ne, Na/K-Ne, Cu-He, and helium. Not all the lamps are well documented. Arc maps are available for the Cu-Ar (La Palma Technical Note 52), Cu-Ne (La Palma Technical Note 35) and Th-Ar lamps (AAO User Manual 4; ESO Scientific Report 6). See Appendix C.

  The comparison lamps have two dedicated ND filter wheels, providing a wide range of ND filtering (La Palma Technical Note 22). These are rarely needed when observing with the CCD.

- **Filters.**

  Two main trays are available for ND and colour filters common to the star and lamp beams. The trays can be loaded with up to 5 filters each (plus a clear position). The filters are 45 mm × 60 mm × 3 mm in size. The two main filter trays are easily accessible, allowing rapid replacement of the trays' contents. Care must be exercised when removing the filter trays, since the two trays (colour and ND) are *not* interchangeable. This is only to be performed by the support staff.

  The colour filters normally available are UG1, BG28, BG38, GG385, WG360, GG495, RG630, RG695 and RG830. The wavelength dependence of transmission of these filters is given in Figure 2.5. The following ND filters are available; ND = 0, 0.3, 0.6, 0.9, 1.0, 1.2, 1.5, 1.8, 2.0 and 3.0.

Figure 3.3: The area within which guide stars may be chosen for use with the autoguider at the Cassegrain focus of the INT. Stars may be selected in the shaded area. If the autoguider probe is moved closer to the centre of the field, then the slit is obscured. Partial obscuration occurs in the area shaded with dashed lines. The field outside the circle is heavily vignetted, but bright stars may be usable. The orientation of the diagram on the sky is given for the instrument rotator in PA = 0°. At other PA's, the diagram must be rotated anticlockwise by the PA.

Chapter 4

A Night on the Bare Mountain

4.1 Observer's hardware

When you arrive at the control room of the telescope, you will be confronted with a series of displays (figure 4.1). You will mainly need to be aware of

- The observer's VDU. Observing is controlled from there. You issue the commands that *control* the spectrograph, A&G box and detector, once they have been configured (after physically changing gratings and collimators).
- The MIMIC display (figure 4.2) is a schematic picture of the A&G box and the spectrograph, showing the status of all relevant components. It is a very useful mnemonic, as tracing down the light path you will encounter everything that matters between the Cassegrain primary aperture and the detector.
- The LEXIDATA display and joystick box. This is where you see the data. The joystick controls the cursor. The switches on the box are used to select alternatives and initiate actions in some graphics programs.

4.2 Introduction to the CCD system

The camera system - shown in figure 4.3 - consists of the following parts:

- The liquid nitrogen cooled camera head which is mounted at the appropriate spectrograph focus.
- The analogue drive box which is mounted within about 2 metres of the camera head.
- The digital controller which is located off the telescope and interfaced to the instrument computer. For data collection the instrument computer uses a disk (and tape) with Lexidata display.

Figure 4.1: INT control room

Figure 4.2: MIMIC display

Figure 4.3: The CCD Camera components

The camera head is an evacuated cryostat which supports (and cools) the CCD behind an anti-reflection coated fused silica window. A preamplifier and temperature controller are attached to the cryostat. There are no moving parts, except the three-point kinematic mount which provides focus and tilt adjustment manually. The drive box contains CCD clock drivers, analogue-digital conversion and associated electronics.

The controller box is programmable via the instrument computer to define the particular mode of operation of the camera; it is linked via a CAMAC module to the Instrument Computer. No electronic adjustments should normally be necessary to the camera system.

Details of camera set-up and routine observations are given in the following sections.

4.2.1 CCD format

Figure 4.4 shows the CCD format, and some associated information. The size of the image area (and in fact the "underscan") are fixed when the chip is manufactured. The size of "overscan" in both directions could be varied if required.

The CCD is mounted with its long axis (horizontal) in the dispersion direction. Row 1 is read out first and appears at the top of the LEXIDATA screen - this is blue on the 235 camera and red on the 500 camera. (Note that the CCD does not maintain the same dispersion direction on both cameras, unlike the IPCS).

It is possible to read out a reduced window of the CCD frame, although the full-frame is recommended for all work at present.

For the GEC CCDs columns 1-11 are "underscan" and not subject to illumination; they can be used to give a zero reference level for the data frame. Columns 12-396 are true image elements. Columns 397-400 are "overscan", as are rows 579-580; these elements contain residual signal and give a measure of any poor charge transfer efficiency in both directions - this can be ignored.

4.2.2 Signal levels, noise and dynamic range

The CCD signal charge is converted to a voltage, amplified and digitised; the computer measures the signal as an analogue-digital conversion unit (ADU). The readout of any signal charge from a pixel has an intrinsic associated electrical noise (see Table 2.1).

There is an artificial, but necessary, electrical offset to the measured signal; this "bias" has a mean level of 100-200 adu but needs to be measured since it is subject to a small drift (up to 10 adu from night to night).

The CCD integrates all light that falls on it and is not subject to any limitation of photon rate. The recommended maximum signals (for linearity) are ~30,000 adu/pixel, although saturation (at 65,535) is permitted without damage. Thus the dynamic range (from max. signal to 3σ) is about 10000.

Figure 4.4: CCD format

4.2.3 Preflashing

Some chips currently in use suffer from a threshold effect such that signal charge below a certain level cannot be transferred within the CCD and therefore cannot be measured. In order to enable weak signals to be measured the CCD is subjected to a brief flash of illumination prior to each exposure. It has been empirically determined that a normal preflash of 40 units is sufficient to give good results for the GEC4 chip (this chip has already been replaced with GEC6). A lesser preflash would not allow weak sources to be correctly detected and a larger preflash increases the Poisson shot noise without significant signal gain.

The normal preflash gives an average signal level of ~25 adu above the "bias" level; this corresponds to ~25 e^-, with an associated shot noise ~5 e^-. Thus the total effective "readout" noise (with preflash) is $\sigma \sim 8e^-$, this is measured as an rms noise of 8 adu.

The preflash illumination is not uniform and increases towards the edges of each row - see Figure 4.5. The level of preflash is however reasonably uniform down the centre of the CCD where a dispersed spectrum would normally lie.

Figure 4.6 shows several 1000 second long-slit exposures of NGC 3310 (a galaxy with a circum-nuclear ring of star formation) with GEC4 covering 3650-9700Å. This example shows the various charge traps as dark columns. Cosmic ray events appear as bright spots. The dispersed spectrum of the object is seen falling-off towards the red wavelength end. Some night sky emission lines are seen. These frames have not had the preflash subtracted and so this modulation of the background is also visible. Figure 4.7 shows the corresponding line-plots.

4.3 Set-up

4.3.1 Technical preparations

Local technical support would have prepared the cryostat before an observing run. This preparation includes cryostat evacuation and filling with liquid nitrogen (check with the telescope operator). It also includes the cryostat mounting and adjustment as follows.

4.3.2 Cryostat mounting and adjustment

The cryostat may be mounted on the 235 or 500 mm cameras; in both cases it is fitted in the same orientation - with its fill tube uppermost above the horizonal axis. A circular mounting ring is bolted onto the spectrograph - this clamps the cryostat with a three-point kinematic location; it allows a tilt/focus adjustment as well as rotation of the cryostat (figure 4.8).

Rough focus, rotation and tilt should only need adjustment when the camera head is changed. This is a difficult process which is performed by local technical support. Fine focus (with collimator) should be checked each night and when extreme grating angle changes are made. It is possible to remove the CCD cryostat and then replace it on the same spectrograph camera without adjustment.

Figure 4.5: A preflash frame obtained with the GEC4 chip in March 1989

Figure 4.6: (a) Unprocessed frame of a 1800 s long-slit exposure of NGC 3310 with λ_c 4300 Å; notice dark columns, bright spots, sky emission lines and [OII] λ 3727 Å.

Figure 4.6: (b) Unprocessed frame of a 1300 s long-slit exposure of NGC 3310 with λ_c 5400 Å; notice H_β and [OIII] $\lambda\lambda$ 4959,5007 Å.

Figure 4.6: (c) Unprocessed frame of a 1000 s long-slit exposure of NGC 3310 with λ_c 6600 Å; notice H_α and [NII]

Figure 4.6: (d) Unprocessed frame of a 1800 s long-slit exposure of NGC 3310 with λ_c 9000 Å; notice dark columns, bright spots, sky emission lines and [SIII] $\lambda\lambda$ 9069,9532 Å.

Figure 4.7: Line spectra extracted from the frames in Figure 4.6; these are the final product

Figure 4.8: A shematic drawing of the cryostat mounting ring

The appropriate CCD field-flattener lenses for each camera must be used. On the 235 camera only an additional 3mm aluminium spacer ring is used. When fitting the mounting ring to the spectrograph take care not to adjust any spectrograph mirror screws!

For the recommended micrometer settings, see the CCD Log-Book in the control room. The micrometers read to 0.01mm, with 0.50mm per revolution. In order to adjust any of the three support points it is important to back off all three micrometers to avoid damaging them, as they are for reading the position **only**. The tightening knobs should be slackened **slightly** to allow the three capstan screws to jack the cryostat in or out. One revolution of the capstan = 0.63 mm. (The micrometers are shortly to be replaced by an electronic sensor).

Clockwise rotation of the capstan screws moves the cryostat outwards and results in a reduced micrometer reading. This corresponds to a positive Hartmann shift if measured Left (HARTMANN 0 1 or OUT IN) then Right (HARTMANN 1 0 or IN OUT) The cryostat is only retained in place by the three clamping knobs so take care to support it when they are loosened.

4.3.3 Logging in

The first thing to do, on approaching the Instrumentation Computer, is to log into it and start up ADAM. This is also described step by step in Section 4.4 (pink pages).

- Check that the system is clear of all other users. Ask, if in doubt.
- Sign on (log in) using the SI command. You should have been allocated a user number (n) in the range 1 to 8; write it down on the board. Use up to four initials to identify yourself.

  ```
  SI <initials>,<n>,<n>
  ```

  If you encounter any difficulties, there may be somebody still logged in at the terminal, so try the command

  ```
  SO
  ```

  and retry the SI command.
- Now, to run ADAM, type

  ```
  ADAM
  ```

- ADAM should now start up and present you with a two level menu. The first choice is the focus at which you are observing (CASS), and the second is the instrument/detector combination IDS/CCD.
- The system now loads the relevant software for your selection and performs some initialisation. You need to answer some questions about the gratings etc. which are fitted to the spectrograph. The computer has no knowledge of these options, but only a memory of what it was last told. If, e.g. a collimator has been changed, you must say so; the support astronomer will have physical access to the spectrograph to change gratings and collimator. Eventually the VDU gives an ADAM prompt

```
Adam:>
```

You can now use any of the ADAM commands described in the next chapter.

Break in

If, for any reason, ADAM goes dead and you don't get the ADAM:> prompt, try the SEND CON: command. It has a similar effect to <CTRL/Y> or <CTRL/C> on the VAX. CON: is a mandatory parameter, and is the name of the ADAM terminal.

This command should only be used when there is no ADAM prompt. It can be issued at other times (e.g. to halt a command that is producing a lot of output), if you first press the BREAK key and the Operating System's "*" prompt is obtained.

Sometimes it is necessary to type an extra c/r to make the command work. On rarer occasions it may be necessary to issue the command more than once for it to take effect. If it still does not work, type CANCEL and then start ADAM again.

4.3.4 Rotation alignment

Data reduction is greatly simplified if the dispersion direction is along one CCD column. A check for rotation of the CCD can be performed as follows. It is best to use a high dispersion (600 or 1200 lines) grating set for the red (6000-8000 Å).

```
IDS OPEN        (camera shutter open)
DEKKER 1        (narrow dekker) with IPCS dekker; DEK 3 with FOS dekker
TUNG ON
COMPMIRROR IN   (light from calibration lamps through the IDS)
SLIT 180
GLANCE 10       (a 10 sec trial exposure)
PHOTOM          (to take a horizontal profile)
```

Use PHOT to take horizontal profiles (figure 4.9) at (a) and (b), i.e. near top and bottom of detector. The effective line centres are printed out. It is best to take the profiles over only about 10 elements and perhaps to sample in one or two places at top and bottom. It is possible to align the rotation to within 0.1 or 0.2 pixel over the length of the CCD. This method gives good setup of rotation; it assumes that the slit is normal to the dispersion direction.

Rotation adjustment if necessary, is achieved by manual movement of the cryostat; the mounting ring has six slotted holes for this purpose (figure 4.8). The 6 bolts should be slightly released and the cryostat should be rotated out of position so as to approach the ideal position in one direction only. The micrometer D should be used only to measure rotation position (not to move the cryostat) although a small degree of backlash/flop can be experienced. An increase of 0.35 mm in the micrometer reading will rotate a dispersion column by about 1 pixel in 500 anticlockwise. The rotation normally only needs setting when the CCD is first installed on the camera, and this will be done by a DT or a SA. Observers should not attempt to make these adjustments themselves.

4.3.5 Tilt adjustment

A check to ensure that the CCD is parallel to the focal plane of the spectrograph follows. By using the routine TILT which is fairly self-explanatory inside the SETUP mode (see section 4.4) one can check that the focus is the same at six different windows. The positions of these windows should include bright arc-lines. In the red, with a high dispersion grating, CuNe lamp is the best one.

```
DEKKER 0
1LAMP ON
SLIT 185
other settings as before

GLANCE 10
```

Following the Glance run check the existence of two intense arc-lines near the top and bottom of the chip. See figure 4.9. Then

```
SETUP            (Loads software for TILT and FOCUS)
TILT             and answer prompts.
exposure time > 10 secs. (when prompted).
```

This routine then does two exposures opening one Hartmann shutter at a time (first LEFT then RIGHT) and finally prints out the shift at 6 positions as above. Note that there is a variation due to the effects of pixel-sampling, i.e. if TILT is repeated shifts may vary by .05 - 0.1.

Tilt correction is achieved by adjusting cryostat screws with care. Approximately 1/2 turn clockwise of screws A, B or C will increase the tilt vectors by ~1 line shift. Screw B should tilt the cryostat (and CCD) about its long axis, aligned with the dispersion direction. It is not possible to adjust tilt without modifying the focus, but hopefully this adjustment should rarely be needed. A change in focus (or tilt) of about 0.1 or 0.2 (Hartmann shift) across the CCD does not seem to be significant; and indeed very time-consuming to perfect.

Referring to Figure 4.8 again, slacken the three locking nuts before attempting to adjust the cryostat position. Movement is effected by the capstan screws. Also remember that the micrometers are for **reading only**, and cannot move the cryostat i.e. back off the micrometer, adjust the capstan and then gently screw in the micrometer and take a reading. For spectroscopic work it is the top-bottom (dispersion) tilt that is most important and for this adjust capstan B. On the 500 mm camera it is found that turning B anticlockwise by 1 1/4 turns, increases top-bottom by 1 pixel.

The best way of being confident about the "tilt" Hartmann shifts provided is to do two tilt set-ups without adjustment between them. The results should be similar in both cases. As with

Figure 4.9: Schematic SETUP procedures

ROTATION, this work should only be done by a DT or a SA and is only necessary when a camera change has occurred.

4.3.6 Focus

This would normally be done with the grating to be used for observation – some gratings are not flat so you cannot guarantee the focus from one grating to another.

The prompts in FOCUS (at the SETUP mode) are self-explanatory. Use a widened slit (~ 300 μ m) to spread the image over several pixels, for accurate line centering. Follow the steps in Section 4.4 (pink pages).

A collimator auto focus routine then occurs in which five collimator steps are taken. A centre-of-gravity line centre is found in order to determine the Hartmann shifts (it was found that the cross-correlation technique depended too critically on the correct arithmetical signal levels). The optimum focus is determined automatically. Finally, type READY to return to normal CCD operations.

4.4 Observation routine

Having finished the set-up, you are ready to observe. This Section goes first over some general concepts and then takes you step by step through your observation routine.

If disk only is selected as the data destination then the number of available CCD runs will be limited by the disk space. CCDSPACE will tell you how much disk space is still available. It is important that users should copy important images to tape as soon as possible and then PURGE so that disk space is not limited. Better still, select tape as the dump device so that every exposure is automatically copied to tape. After the D-tape has been copied to a C-tape by support staff (or the observer if he has time!), the disk can be purged and overwritten if necessary. The EAGLE disk has space for $\sim$ 500 CCD runs. At least 60 CCD images can be stored on a 2400 foot tape (1600 bpi). The tape writing gives a slight overhead to the duration of an observation - although the next one may be started during tape writing. However, the Lexidata must not be used whilst tape writing proceeds. Only if you have many short exposures may you choose to dump the data to disk and then FITSOUT the runs to tape at the end of the night. But remember that the data is **not** safe until it has been written to tape. The EAGLE disks failed twice in 1988 with loss of all the data on the disk in both cases.

An estimate of the bias level is used by the software when it does correlations or similar operations. This bias level is an electrical zero offset within the CCD camera and can be measured from the "underscan" portion of an exposed image (see Appendix B). The bias level may be measured using PHOTOM/STATS after taking the first exposure, and the software default may be corrected if necessary (using a command BIAS b where b is the value to be entered).

If preflash is needed for your chip (find out from your SA) the level should be set for all observations. At present the default is zero, use PREFLASHDEFAULT=n to reset the default.

The normal high-level command that is used for an observation is of the form RUN t "NAME", where t is the exposure time in seconds and NAME is your object. Several (n) equal exposures (of t seconds) can also be obtained using the command MULTRUN n t "NAME". Such exposures are recorded on a sequential series of disk files and would be written to tape, if selected. An alternative method for a trial exposure is to use GLANCE t, where the image is put in a scratch-file which is overwritten by the next GLANCE. This image can be kept permanently if desired, by using the command KEEP "NAME" before another GLANCE is performed.

A RUN consists of various lower-level operations as follows: telemetry check, clear chip, timed exposure, readout to disk, display, (copy to tape). The above operations take about 1, 4, t, 30, 5 (and 60) seconds respectively. The PHOTOM and SPECTRUM utilities make available several basic image/data analysis options for use by the observer. There are also other more general facilities such as image arithmetic operations, IPCS external memory usage, etc. Chapter 5 summarises the ADAM software commands.

No temperature reading or other monitoring of the CCD camera is provided directly. The remote telemetry is automatic and only becomes visible to the user if a fault develops (see also the ADAM command TELEM).

After initializing the system and doing the SETUP, the following frames should be obtained:

The zero bias frame - a 0 second exposure with preflash = 0. In fact about 10 of these can be taken and averaged to give best results. This yields a frame which records any modulation of the zero level, which should be small ($\leq$ r.m.s. noise level σ). The centre of a single frame can be examined using PHOTOM/STATS to check the performance. The mean level should be = "bias" ($\pm$ 10) with a σ of 5-6 (e.g. over an 11 x 11 box).

A preflash frame - a 0 second exposure with normal preflash. This should give a central mean value $\sim$ "bias" + 25, with $\sigma \sim 8$. The shape of the preflash should appear similar to the standard example (section 4.2). Take several and average.

A preflash map - a zero second exposure with preflash = 400 (for normal preflash=40). Use the SETFLASH 400 command. This provides a map which may be scaled and subtracted later. The chip readout will automatically restore the preflash to the nominal value (now zero).

A flat-field - a tungsten flat-field may be taken although a diffuse sky flat-field is much better. Note that without corrections the pixel-pixel response variations should be $\sim$2% r.m.s.

4.4.1 Afternoon Activities

- Contact your SA (from Residencia, use radio or intercom to ask for Duty Officer)
  [CCD should be on and cooled, TILT and ROTATION checked.]

- **COMPUTERS.**
  Start up Perkin-Elmer ICS3220 if necessary (will give "*" prompt).
  (See notes on wall by system console, in the tape-drives room)

- **LOGIN.**
  Check that the system is clear of other users, ask if in doubt.
  SI XYZ,n,n (write initials on board and dates resident)
  ADAM

- opportunity to change grating, collimator, etc.

- enter next archive image no. (for Grinnell TV images)

- enter chip installed (e.g. GEC3)

- dump to disk

- take default bias setting for now, or use value on board

- check MIMIC display; is everything okay?

- EXGRAT (to improve encoder accuracy for grating angle)

- if PREFLASH is needed (check with your SA) type:

```
PROC CORRE T
SETFLASH 40        (if that is the advised value)
RUN T "NAME"
END PROC
```

and

```
PROC MIRA T
SETFLASH 40
GLANCE T
END PROC
```

use these procedures instead of RUN or GLANCE.
ENABLE the flash at the CCD camera head.

– type in the following 2 procedures:

```
PROC ARCON
IOPROCEED 1
COMPMIRROR IN
1LAMP ON           this will be normally the CuAr lamp
IOPROCEED 0
END PROC
```

and

```
PROC ARCOFF
IOPROCEED 1
COMPMIRROR OUT
1LAMP OFF
IOPROCEED 0
END PROC
```

(if you want CuNe instead, normally you have to type 2LAMP)
Use PUT (and GET) to save (and retrieve) your procedures, otherwise they are lost each time you exit ADAM.

– **FOCUS.**
If you are going to use more than one collimator or grating, check that the focus has not changed with each configuration.
NOPACKETS (saves time during set-up, but remember to turn back on to observe using NOPACKETS=0)
GLANCE 0 and use PHOT in STATS mode to determine bias level, b. Then BIAS b
GSMOVE OPEN (opens grating shutter)
IDS OPEN (opens spectrograph shutter)
GRAT_ZERO 89.75 (check board for current value, check it using known arc

lines.)
CENWAVE λ (where λ is in Å). You will need 2 strong, unconfused arc lines near the ends of the chip for focussing. Use the arc plots to help you choose. With CuAr, λ7500 is a good region.
SLIT 300 (150) for 235 (500) cameras.
ASCF 2 inserts GG495 for red observing (to cut out 2nd order blue).
ASND 0
ND 0 (arc filters not usually needed with CCD).
GLA 5 (use a double length period for the Hartmann exposures) and then examine spectrum with
PHOT to make sure the lines are not saturated.
Lexidata buttons are :

Exit	Mode	Down	Reset	Up	BLUE

The BLUE button is used to mark the cursor position.

SETUP (makes ROT, TILT and FOCUS available for use; note that a FOCUS adjustment has to be made after checking ROT and TILT)
ROT Should already have been set (see 4.3.4)
FOCUS performs Hartman tests for 5 collimator positions (or just 1 if a step of 0 is used). Note that shifts are given in 1/10 pixels. Takes about 15 mins.
An alternative procedure if you have problems with FOCUS is
TILT also performs a Hartman test (but for the current collimator position only). For the 2 chosen lines it gives, in addition to the mean shift, the L-R (along slit) and T-B (along spectrum) shifts. These should already have been minimised when the CCD was first set up by the SA. Hence minimise the mean shift by trying several collimator settings, using
COLL n (where n should be in the range 170 - 240.)

READY (to return to observing mode).

- **FLAT FIELD**
  This is potentially dangerous if the IPCS is also up. Check the Mimic display and keep an eye on the HP display.
  Use the TUNG lamp at CENWAVE 7500 and some ND (1-2) with a wide ($\geq 200\mu$) slit to minimise dust streaks. However, you should also do a flat field at your observing setting to calibrate any such streaks. (Note that issuing TUNG will automatically set ND to its maximum value; you have to adjust them.)

  Do flat field in second order (i.e. CENWAVE 14000) if low dispersion grating is used.

4.4.2 Twilight/Evening Activities

- **TAPE.**
  Mount latest D tape, and record in log book in computer room.
  DATA (and answer questions). If integrations are short or MULTRUN is in use, then just dump data to DISK and use FITSOUT to write data to tape at end of night.
  (Maximum of 60 full size CCD frames per tape)

- **NORMAL OBSERVING**
  CCDSPACE (to find out how much space is available on disk)
  PACKETS (for data to be kept)
  To change TV filter settings use:

TVF	0	clear	normal use
	1	green	for seeing measurements
	2	blue	useful for blue stars at high Z.D.
	3	red	useful in bright moon

  CHANGE (to change grating or anything else in IDS)
  RUN t "NAME" (or CORRE if using preflash and you have used this name for the procedure for t secs observation)
  MULTRUN n t "NAME" (for n observations of t secs each)
  KILLMULTRUN (if you want to stop MULTRUN for any reason)
  GLA t (glance, or MIRA if using preflash; stores data in temporary file R0)
  KEEP "NAME" (keeps the last GLANCE run)
  RUNSTAT (how long RUN has been going)
  DISP Rn (to display an earlier run, number n)
  If you want to keep the Grinnell image, ask the T.O. to ARCHIVE it for you.
  DISP An (to display an archived TV image)

- **ON-LINE DATA REDUCTION**
  SPECTRUM (for quick-look on-line analysis, just follow the instructions)
  Use temporary files T1, T2, etc to store output spectra in, then
  PLOT T1 and use default values for all plot parameters except Scale Factor, where values of 10-100 are likely to be needed. A plot appears on LEXIDATA.
  SPECPLOT T1 as PLOT, but gives wavelength scale and a cursor.
  When plot on LEXIDATA looks okay, use
  LEXPLOT to get a hardcopy of it on the Printronix.
  (N.B. LEXPLOT takes 40-45 secs and should not be attempted close to the end of a run as it doesn't like you to use LEXIDATA simultaneously).

- **Useful Hints**
  Use CuNe arc for Hα work, otherwise CuAr for red. This depends on dispersion, look at Appendix C.
  Check that your flux standards are calibrated for $\lambda \geq 8000\AA$. Look at Appendix A.
  F8 stars make good calibrators for removing atmospheric absorption bands for red

spectra and are common.

- **BIAS FRAMES.**
  RUN 0 "BIAS" (~5-10 times, when dark, for accurate estimation of bias)
- **PREFLASH FRAMES** (if needed)
  CORRE 0 "PREFLASH" produces a RUN with PREFLASH 40 units.
  SETFLASH 400
  RUN 0 "FLASHMAP" produces a FLASH MAP of 400 units (convenient if your default value is 40 units) that you will scale to the used default value when reducing your data.

- **COPYING DATA.**
  Fill in Tape Copy Request Form and place in tray with D tape for Duty Officer to collect; do it every morning, do not wait until your final night. The C tapes will appear in the INT Visitors' pigeon hole.
  D.I.Y.:
  FITSINIT (INTD__) for first time use.
  FITSOUT (e.g. R1-R60) data is written to tape in International FITS standard since 16th January 1989; see Appendix B.

4.4.3 Morning Activities.

- **CLOSEDOWN.**
  Dump all data to tape
  SHUTDOWN
  Stop ICS computer (see notes on wall in the tape-drive's room).
  Telescope Operator will refill liquid nitrogen in CCD cryostat.
  Fill in tape request form (and feedback form on your last night).
  Go to bed.

4.5 Observing with the Cross-disperser

Mounting the Cross-disperser

The cross-disperser is mounted next to the folding prism; it will have been done by the SA following this procedure:

- Remove the lid at the bottom of the IDS.

- One of the **three** mounting screws has been marked A, hold it in front of the corresponding hole and then rotate the unit 120°counterclockwise.
- Insert the unit and rotate 120°back.
- Fasten screws and put lid back.
- Keep calm. It might take 1/2 an hour to do it the first time.

Tips for Observing with the Cross-disperser

Here are some practical tips for observing with the Cross-disperser.

- Focusing is best done with a R1200Y grating and the Copper Neon lamp.
- There is no software to extract the orders on-line, however, FOS software can be used afterwards to extract about three orders. This is easily done because they are **straight lines** (see figure 4.10).
- Wavelength calibration is rather difficult due to the lack of a lamp with wide wavelength coverage. A planetary nebula (such as NGC 7027) can be used. Figure 4.10 shows maps of the CCD images for grating angles of 60.75°, 60°and 59.25 °with enough lines even in the ultraviolet. See also Table 3.3.
- Do not use a grating angle outside the range 60 ± 1 °, otherwise the efficiency falls off rapidly.
- The FOS-dekker is best used, in order to ensure that there is no overlap of orders in the spatial direction. It has a 24.5 arcsec long slit which is ideal for use with the cross-disperser.

Figure 4.10: (a) A spectrum using the IDS cross-disperser and a grating angle 60.75°. Orders (3) to (8) can be seen.

Figure 4.10: (b) A spectrum using the IDS cross-disperser and a grating angle 60.°. Orders (3) to 8 can be seen.

Figure 4.10: (c) A spectrum using the IDS cross-disperser and a grating angle 59.25°. Orders 3 to 8 can be seen.

Chapter 5

ADAM

5.1 Introduction

One of the features of ADAM is the ability to define command procedures which can be used just as though they are normal ACL (ADAM Command Language) commands. The philosophy adopted for the CCD software is to provide commands at several levels. At the top level are commands that can be used by those requiring a high-level system. These commands are, where possible, similar to those of the ADAM IPCS software (which are in turn similar to those of the AAT IPCS software).

In addition some of the commands used by the high-level system, such as CLEAR (the chip), EXPOSE (for t seconds), READ (the chip to disk), DISP (on the Lexidata) and TAPE (write data to tape as a FITS image), are documented in the expectation that astronomers will build their own observing procedures from these building blocks.

Included in the standard ADAM software are a set of application programs for displaying and manipulating bulk data arrays. The enthusiastic astronomer may bring his own application programs and run them as part of ADAM. Alternatively observers may contact their Support Astronomer concerning facilities that are not currently provided.

In command descriptions, the minimum abbreviation is indicated by putting the optional part in parentheses. For example, GLA(NCE) is abbreviable to GLA but not inside procedures where the full command name is required.

5.1.1 HELP

The HELP command inside ADAM can be used to obtain on-line information. There are several levels of HELP. A glossary of commands is given in Section 5.7 separated according to topic.

Parameters

Any parameters are the topics on which help is required.

Examples

Adam:> HELP CCD
Contains information concerning the CCD subsystems.

Adam:> HELP CCD SUMMARY
Gives a glossary of the commands that can be used to control the CCD cameras.

Adam:> HELP FITS
All data is written to tape at 1600 bpi in FITS format (see Appendix B). Information can be obtained from

Adam:> HELP FITS COMMANDS SUMMARY
Which gives a glossary of commands.

Adam:> HELP ACL SUMMARY
Gives a summary of entries in the ADAM Command Language library.

Adam:> HELP ACL_FACILITIES SUMMARY
Summarises extra ACL facilities.

Adam:> HELP LEXIDATA SUMMARY
This gives a summary of the programs that can be used to display data or give commands to the LEXIDATA image display device.

Adam:> HELP UTIL SUMMARY
Contains a summary of the utility commands available.

Adam:> HELP TCS SUMMARY
Contains the commands applicable to the Telescope Control System user interface.

Adam:> HELP SPEC SUMMARY
Here are summarized the commands applicable to the IDS that are available to the observer.

Adam:> HELP AGBX SUMMARY
Gives the commands applicable to the A&G box that are available to the observer.

Some of the CCD control commands are discussed in what follows.

5.2 CCD Control commands

These commands are described beginning with the higher level ones and ending with the lower level ones that are useful in procedures.

GLA(NCE) - a trial exposure

Performs a trial exposure, always into the same file :

```
1. Clear the chip unless NOCLEAR flag is set
2. Pre-flash if non-zero pre-flash time set
3. Expose (open shutter, time exposure, close shutter)
4. Read out chip
5. Reset the pre-flash time to the default (0 at present)
6. Display data on the Lexidata
```

Parameters

A single parameter, the exposure time in seconds, is expected. If omitted, it will be prompted for.

Examples

Adam:> GLANCE 1.5

Perform a GLANCE run with a 1.5 second exposure.

Notes

During the GLANCE run (which will normally be short), nothing else can be done on the ADAM terminal.

If the exposure time is zero the shutter is not opened at all.

The pre-flash period can be set by using the SETFLASH command before the GLANCE command.

RU(N) - the primary exposure command

Performs a run, always into a new file :

1. Check telemetry
2. Clear the chip unless NOCLEAR flag is set
3. Pre-flash if non-zero pre-flash time set
4. Expose (open shutter, time exposure, close shutter)
5. Read out chip
6. Reset the pre-flash time to the default (0 at present time)
7. Display data on Lexidata
8. Write data to disk
9. Write data to tape as FITS image if tape is selected dump device
10. Increments next run number

Parameters

As for GLANCE, the exposure time in seconds, prompted for if omitted.

The object name can be given as a second parameter. It should be in double quotes and will be prompted for if omitted. The object name is limited to 24 characters.

Examples

Adam:> RUN 1000 `"NGC4151 long-slit"`

Perform a 1000 second run looking at NGC 4151. This is the most efficient way of starting a run as nothing happens until all prompts are answered.

Notes

During all but the briefest runs, the ADAM terminal is available for displaying the RUNSTATus, PAUSEing, CONTINUEing, STOPping, ABORTing and running application programs.

All runs are timed using the Time Service, giving exposure durations accurate to about one millisecond.

PA(USE)/CONT(INUE)/STO(P)/ABO(RT) - run control (1)

Pause / continue / stop / abort an active run. For PAUSE, the timer is stopped and the shutter is closed. For CONTINUE the timer is restarted and the shutter is opened. STOP behaves exactly as though the timer period had expired. ABORT stops dead without reading out.

Parameters

None

Examples

Adam:> PAUSE
Adam:> CONTINUE

Notes

The PAUSE command will be rejected if a run is not currently active.

The CONTINUE command will be rejected if a run is not currently PAUSEd.

RESTART

This command will be needed only under one very specific circumstance: a CCD exposure is running and ADAM crashes for any reason, e.g. power failure.

Parameters

None

Notes

On RESTARTing ADAM the run active bit may still be set in the CCD controller. If this is the case, the software detects the fact and asks you to type RESTART when the ADAM:> prompt appears. Only after RESTARTing are you able to do further RUNs or GLANCEs.

RUNSTAT(US)/TIM(E) - run control (2)

RUNSTATUS says whether a run is active or paused and prints the current elapsed time. TIME alters the exposure time for the current run.

Parameters

RUNSTATUS has none. TIME has one, the new run time in seconds. If omitted, it will be prompted for.

Examples

Adam:> RUNSTAT
Adam:> TIME 100

TEL(E) - system telemetry

Read and display telemetry values, indicating which ones are out of range.

Parameters

The default is to output only those values that are out of range. If called with QUIET=F, all values are listed. If called with HEADER=T, a heading is printed.

Examples

Adam:> TELE QUIET=F   List all values

CLE(AR)/NOCLEAR)/EXPO(SE)/REA(D) - home-made runs

CLEAR clears the chip, NOCLEAR suppresses CLEAR on the next GLANCE or RUN, EXPOSE t exposes for t seconds and READ reads out the chip to the GLANCE file.

Parameters

Only EXPOSE needs a parameter. It is mandatory and is the exposure time in seconds.

READ will assume the GLANCE file, but if a parameter is specified, it will be taken as the file into which to read.

Examples

Adam:> CLEAR clear the chip
Adam:> NOCLEAR Don't clear the chip on the next GLANCE or RUN
Adam:> EXPOSE 10 expose for 10 seconds
Adam:> READ read out the chip

Notes

If t=0, EXPOSE does precisely nothing.

QFL(ASH)/SETFLA(SH)/FL(ASH) - pre-flash control

QFLASH prints out the currently selected pre-flash time, measured in arbitrary units of about 1 microsecond. SETFLASH sets up this time. The actual flash is performed automatically prior to a GLANCE or RUN, or on demand using the FLASH command.

Parameters

QFLASH requires none. SETFLASH requires the pre-flash time. If omitted, it will be prompted for. FLASH requires none since it uses the time previously set up by SETFLASH.

Examples

Adam:> SETFL 10
Adam:> FLASH

Notes

SETFLASH does no more than set a microcode variable governing the flash period. It performs no flash. To disable pre-flash, give a zero flash time. If the preset FLASH time is 0, FLASH does nothing.

Default pre-flash can be set with PREFLASHDEFAULT=n. If you change the pre-flash default ,use always SETFLASH before starting a RUN. PREFLASHDEFAULT just sets up a parameter, SETFLASH actually sends it to the CCD controller.

SHUTDOWN - close ADAM

Use this command to close down ADAM.

Examples ADAM:> SHUTDOWN   the prompt will change to
$\star$ SO   to sign off from the Perkin Elmer

Notes

SHUTDOWN closes all shutters, switches off lamps, etc, and puts the instrument into a well defined state.

5.3 LEXIDATA display operations

DIS(P) - display an image

Displays an image on the Lexidata. This will not often be necessary when using the high-level commands, since both GLANCE and RUN do an automatic display. NODISP=1 will disable automatic display. To reset type NODISP=0.

Parameters

There are some, but default values will normally be acceptable. By default, the current image is displayed unscaled and centred in the centre of the Lexidata screen.

Examples

Adam:> DISP

Notes

When displaying an image that has a dimension larger than 512, the parts that lie outside the Lexidata are not displayed. To get round this problem it is best to rotate the image on the Lexidata (it has 640 pixels in the horizontal direction which is sufficient to show afull GEC CCD image). The rotation on the Lexidata is controlled by three parameters XYSWAP, LRSWAP and TBSWAP which by default are set to 300.

For the 235mm camera type

ADAM:> XYSWAP=1
ADAM:> LRSWAP=1

for the 500mm camera type

ADAM:> XYSWAP=1
ADAM:> TBSWAP=1

This will rotate the images so that longer wavelengths are to the right.

Use DIPARM to alter the scaling option (note that it is faster **not** to scale the data and **much** faster, when scaling, to leave LOW=0, since, where possible, scaling is done using shift operations.)

QDI(PARM)/DIP(ARM) - enquire and alter display parameters

QDIPARM prints what the current display parameters are. DIPARM alters them. Initially no scaling will be performed.

Parameters

QDIPARM requires none. For DIPARM :

option - 1, 2 or 3 for scaling options NONE (no scaling), FOLD (scale with wraparound) and TRUNCATE (scale with no wraparound) respectively

low - if option>1, data value to map to minimum intensity

high - if option>1, data value to map to maximum intensity

If omitted, all parameters are prompted for.

Examples

Adam:> DIPARM 1   scale = NONE

Notes

QDIPARM will print the current scaling values.

If the parameters are omitted, so a prompt is issued for option, the user response should be N, F or T, not 1, 2 or 3, and a response of "?" will show what the acceptable responses are. This comment is also true of the DATA, MODE, SMVAR and GMVAR commands.

For maximum information content, the FOLD scaling option is recommended.

PHOT(OM) - simple statistics and profile utilities

Interacts with the image currently displayed on the Lexidata. The program has several modes of operation which are described briefly below. The user interaction is performed entirely with the Lexidata trackerball / joystick and switches. Each switch has a specific meaning which is common to all the Lexidata programs.

The Lexidata joystick and switches

The Lexidata joystick has six switches. These are labelled, from left to right, EXIT, MODE, DOWN, RESET, UP and READ. All Lexidata programs that use the switches light up only those which they use and give each switch an interpretation which is in the general spirit of its label. The general meanings are :

```
1. EXIT  - Exit from the program
2. MODE  - Cycle through various options presented by the program
3. DOWN  - Decrease some quantity or quantities
4. RESET - Reset some quantity or quantities
5. UP    - Increase some quantity or quantities
6. READ  - Read the cursor position (Blue button)
```

Notes

It is always the change in state that is important, never the actual position of the switch.

There are six modes of operation, and the MODE switch is used to cycle through them. The initial mode is "Profile", followed by "Stats", "List", "Zoom", "Cursor" and "Dist" respectively. The RESET switch always unzooms the image and sets everything back to its default value. The EXIT switch always causes immediate program exit.

The behaviour of the remaining switches, READ, DOWN and UP, is described for each mode :

1. **PROFILE** - The READ switch causes a profile to be drawn from the previous cursor position to the current position. Currently only horizontal and vertical profiles are permitted. The UP and DOWN switches control scaling - initially data is truncated at 16383 and DOWN halves the cutoff, UP doubles it
2. **STATS** - The READ switch causes statistics of a rectangular neighbourhood of the current position to be listed on the terminal. These include a sky estimate based on the rim of the box, estimate of sky-subtracted flux, standard deviations and maximum/minimum pixel values within the box. The UP and DOWN switches control the box size - initially it is of side 11 and DOWN decreases it by 2, UP increases it by 2
3. **LIST** - The READ switch causes the pixel values of a rectangular neighbourhood to be listed on the terminal. The box is the same one as used by STATS and its size is controlled in the same way using the UP and DOWN switches
4. **ZOOM** - The READ switch causes the image to be zoomed about the current position with the current zoom factor. The UP and DOWN switches control the current zoom factor - initially it is whatever it was on entry to PHOTOM. DOWN decreases it by 1, UP increases it by 1
5. **CURSOR** - The READ switch merely echoes the current position in pixel and user coordinates, plus the corresponding data value. In fact this information is given in all modes. The UP and DOWN switches control the box size in the same way as in the STATS and LIST modes
6. **DIST** - The READ switch causes the distance between the current position and the last position to be calculated (in pixels) and listed on the terminal. The UP and DOWN switches control the box size in the same way as in the STATS and LIST modes

Parameters

There are some, but they should not normally be necessary when running within the CCD system.

Examples

Adam:> PHOTOM

Notes

PHOTOM, in common with all the Lexidata programs, will automatically use the current image, i.e. the one that has most recently been read from the CCD.

PHOTOM uses the BIAS value given at startup when it estimates line centres. A better value can be estimated using PHOTOM in STATS mode or else the STATS utility. BIAS can be updated using the BIAS command.

The pixel coordinates of the last two points selected in PHOTOM are written as ACL variables PHOTOM_PXX1, PHOTOM_PXY1, PHOTOM_PXX2 and PHOTOM_PXY2. Thus PHOTOM can be used in a procedure as an easy way of getting two points selected by the user.

SPECTRUM/SPECPLOT - crude on-line data reduction

SPECTRUM allows a simple extraction of a 1-D spectrum, sky subtracted, and SPECPLOT will plot the spectrum with a crude wavelength scale. These are described in detail in Section 5.6

Lookup table and other Lexidata commands

The following commands are available:

```
1. CLOV(ER)      - Clear the Lexidata overlay planes
2. LEXINI(T)     - Reset the Lexidata and load an appropriate lookup table
3. LEXCL(EAR)    - Clear or reset the Lexidata
4. LEXPA(N)      - Pan and zoom
5. LEXZOO(M)     - Zoom by hand with specified factor about specified
                   position
6. LUTCON(TRAST) - Manipulate the lookup table to enhance contrast
7. LUT(LOAD)     - Load a lookup table (try COLS, GREY)
8. LUTROT(ATE)   - Rotate the lookup table
9. UNZ(OOM)      - Return to an unzoomed and unpanned state
```

5.4 Data file control

Image storage

The file handling commands present a view of the disk as :

1. The current image
2. The GLANCE file
3. A set of RUN files
4. A set of STORE files
5. A set of TEMPorary files

The current image can always be referred to as IMAGE and the GLANCE file as GFILE. A set of variables RUN, STORE and TEMP can be used as shorthand to refer to RUN, STORE and TEMPorary files. For example, R1 is RUN number 1.

Examples

Adam:> ADD GFILE R1 T1

adds the glance file to RUN 1 and stores the result in TEMP 1.

QFILES or PRINT IMAGE will always give the name of the current image, and IMAGE=< *val* > will alter the current image. For example to make the current image the first STORE file :

Adam:> IMAGE=STORE1

NEXTR(UN) - change next run number

Alter the next run number. If the run number is reduced then it is possible to overwrite an existing run. This is not allowed unless that run has already been successfully archived to tape.

Parameters

The next run number. Will be prompted for if omitted.

Examples

Adam:> NEXTR 23

KEE(P)/STO(RE)/REC(ALL) - image file handling

KEEP promotes the GLANCE file to be a run file and writes it to tape if the tape is the dump device. RECALL makes a previous run the current image. STORE stores a run in a store file for safe keeping.

Parameters

KEEP requires the object name for the glance image. RECALL requires the run number to recall, and STORE requires the run number to store and the store file number in which it is to be stored. All are prompted for if omitted.

Examples

Adam:> KEEP CuAr-arc
Adam:> REC 10
Adam:> STORE 10 3

DEPROTECT

This command will deprotect your glance file if it has become protected. Normally it is unprotected and so it gets overwritten by each new GLANCE. If for any reason a CCD exposure cannot be read into its correct run file, it is automatically dumped into the glance file which becomes protected so that unless specific action is taken, it cannot be overwritten. The specific action may be KEEP (to copy to the next available RUN file) or DEPROTECT.

DIR

Will list all the files in your account.

OBSN(AME) - change observer's name

Alter the observer's name. By default the observer's name is the initials with which you signed on to ADAM. It is used to generate the names for RUN, STORE and TEMPorary files.

Parameters

The new initials to use. If omitted they will be prompted for.

Examples

Adam:> OBSNAME ET

COM(MENT) - add comments to current run

Add comment descriptors to the current run.

Parameters

None. When prompted, type in as many comments as required and terminate input with a blank line.

Examples

Adam:> COMMENT
Comment>This is a comment
Comment>

Notes

Of course if the run has already been archived there is not much point

COPY - copy one image to another

Copy one image to another. All descriptors are copied as well.

Parameters

Two are required - the name of the input file and the name of the output file. If omitted they will be prompted for.

Examples

Adam:> COPY GFILE STORE2	Copies GLANCE file to 2nd STORE file

PUR(GE) - delete run files from disk

Delete run files from disk.

Parameters

Five are required - the name of the disk, the name of the detector being used, the observer's initials, the first run number to be deleted and the last run number to be deleted. If omitted, all are prompted for.

Examples

Adam:> PURGE SYS CCD ET 1 10

Notes

If a file has not yet been archived to tape PURGE checks that you REALLY want to delete it. PURGE is not recommended until you have your data safely on your personal C(opy) tape.

DAT(A) - redefine the dump device

Redefine the dump device and select the next run number.

Parameters

It's easiest to reply to the prompts! If changing to using tape, FITSDIR is run to determine the next run number by reading from the tape what the last run number was. If changing to using disk only, you are prompted for the next run number.

Examples

Adam:> DATA

TAP(E) - write current image to tape

Write current image to tape. As soon as the tape write has started the ADAM prompt is given and you can continue with runs etc.

Parameters

None

Examples

Adam:> TAPE

Notes

TAPE assumes that the tape is positioned between a double tape mark. If not, the tape is advanced in search of one and the file is appended.

When TAPE has finished, the message "Tape dump verify complete" is output. A second TAPE command can be issued whilst TAPE is active but this will initiate a wait until the first one completes.

The data on tape is always verified against the disk data.

FITSINIT/FITSDIR/FITSOUT/FITSIN - FITS tape utilities

FITSINIT initialises a tape for writing data from disk. FITSDIR lists details of FITS images already on tape. FITSOUT writes a FITS image to tape (see Appendix B). It's used by TAPE. FITSIN reads a FITS image from tape to disk.

Parameters

Respond to prompts.

ARCH(IVE) - write set of runs to tape

Write a contiguous set of runs to tape. After having successfully done this there is an option to PURGE the files from the disk.

Parameters

Two are required, the first and last run numbers to be archived. If omitted, they are prompted for.

Examples

Adam:> ARCHIVE 10 20

Notes

This command is not recommended, better use FITSOUT. Do not delete data from disk until your Copy tape has been produced.

5.5 Miscellaneous commands

QCH(IP)/CH(IP) - enquire and alter chip type

QCHIP prints what the current chip type is. CHIP alters the chip type.

Parameters

QCHIP requires none. CHIP requires the chip's name or alternatively will prompt if the parameter is omitted.

Examples

Adam:> CHIP GEC4

Notes

Altering the chip type automatically alters the readout window to correspond to the physical chip size.

When changing chips, the control store is automatically loaded, read back and checked.

QBI(AS)/BIA(S) - enquire and alter bias level

QBIAS prints what value the system is currently assuming for the chip bias level. BIAS alter it.

Parameters

QBIAS requires none. BIAS requires one, the new bias level. If omitted, the current bias is shown, and a new value will be prompted for.

Examples

Adam:> BIAS 200

Notes

The bias level is used in various parts of the system. For example, PHOTOM subtracts it before estimating centres of gravity, and so does the automatic FOCUS procedure.

QWIN(DOW)/WIN(DOW) - enquire and alter readout window

QWINDOW prints what the current readout window is. WINDOW alters it.

Parameters

QWINDOW requires none. WINDOW requires four, which are (XSTART,YSTART) and (XSIZE,YSIZE) respectively. The co-ordinate system is that of the chip relative to (1,1) which is the light sensitive pixel at the corner from which it is read out. (XSTART,YSTART) defines the bottom left corner of the read out data and (XSIZE,YSIZE) are its dimensions.

Examples

Adam:> WINDOW 1 385 1 576

Notes

Overscan can be achieved by making XSIZE or YSIZE such that the image exceeds the physical chip dimension.

To restore the default window the easiest course of action is to issue the CHIP command. This reloads the microcode and resets the default pre-flash time. Alternatively you can issue the DEF_WINDOW command which will simply reset the window parameters back to their default values.

BIN/UNBIN - on-chip binning

BIN selects (UNBIN resets) on-chip binning. You are prompted for the binning factors in X (the short axis of the chip) and Y (the long axis). The binning factors range from 1 to 4.

QFI(LES) - determine current image etc

QFILES says what the next run number will be, what the current image is and what the current dump device is.

Parameters

None

Examples

Adam:> QFIL

5.6 Selected data processing facilities

There are a lot of standard application programs which are available, and, as mentioned in the Introduction, enthusiastic astronomers can bring their own with them. How do these interact with the CCD data acquisition system?

All of these programs use a set of standard routines for reading their input parameters and if such a program ever issues a prompt for a data file name, you can always either type the actual file name (if you know it), the name of an ACL variable whose value is the file name or else a name of the form Rn (meaning run number $< n >$), Sn (meaning store file $< n >$) or Tn (meaning temporary file $< n >$). The name of the current CCD data file is always held in the ACL variable IMAGE, so to operate on the current image, you can always type IMAGE.

Examples

Adam:> PEEP
Enter name of data file :>IMAGE
Adam:> STATS
Enter name of data file :>R4

ADD/SUB/DIV/MULT - image/image arithmetic

These programs perform the basic arithmetic operations on images, in all cases producing an image of the same type and shape as the two input images. They will operate on Integer*2, Integer*4, Real*4 and unsigned 2 byte integers (U*2) images. Raw CCD images are in U*2 format.

Parameters

Each requires three, the first input image, the second input image and the output image. If omitted, they will be prompted for.

Examples

Adam:> SUB R1 R10 T1

Notes

ADD is the "smartest" of the programs at present. If it produces a result that can not fit into the data format, it will prompt you for an appropriate BSCALE factor. The other programs simply truncate the result.

CADD/CSUB/CDIV/CMULT - image/scalar arithmetic

These programs perform the basic scalar arithmetic operations on images, in all cases producing an image of the same type and shape as the input image. They will operate on Integer*2, Integer*4, Real*4 and Unsigned 2 byte Integer images.

Parameters

Each requires three, the scalar, the input image and the output image. If omitted, they will be prompted for.

Examples

Adam:> CADD 100 IMAGE T1

Notes

These programs will truncate the output result if it would overflow the data format.

SQEL/EXTRACT - spectrum/sub-image extraction

SQEL adds together a contiguous set of rows or columns of a 2D image to give a 1D image. EXTRACT extracts a 2D sub-image. Together with the image arithmetic utilities they can be used to calculate buildups, sky-subtract etc.

Parameters

SQEL requires five, the input (Integer*2) image, the output image, the direction in which to add (X or Y) and the range of rows/columns to add.

EXTRACT requires six, the input (Integer*2) image, the low X limit, the high X limit, the low Y limit, the high Y limit and the output image. If omitted, all parameters are prompted for.

Examples

Adam:> SQEL R1 T1 X 100 104
Adam:> EXTRACT R10 100 109 1 580 T2

SPECTRUM/SPECPLOT - On-line data reduction

SPECTRUM is a program to perform quick on-line data reduction. You just have to follow the instructions. It obtains a 1-D spectrum from an area that you select with the cursor, subtracts from it the chosen sky and stores it in a T(emporary) file that you can plot. SPECPLOT Tn gives a plot with the wavelength scale and a cursor.

SPECTRUM lets you delimit the object area with the Lexidata cursor. You have various options when selecting the sky area. You can chose not to define a sky area, a sky area which does not include the object area or a sky area which includes the object area. For this last choice (which takes the longest to execute), the sky under the object is interpolated by fitting a quadratic function to the sky on either side.

Notes

If, to improve the signal-to-noise ratio, you are using the sum of more than one RUN, SPECPLOT will produce a normal PLOT, without the wavelength scale. This is because, at present, the image manipulation routines do not propagate al the necessary headers to the output file. SPECPLOT labels the wavelength scale based on the given central wavelength and a linear dispersion scale.

5.7 Glossary of commands

5.7.1 Summary of CCD commands

This gives a summary of the commands that can be used to control the CCD cameras on the INT. It is obtained on-line by typing HELP CCDSUM

```
Command   Parameters                   Description

ABO(RT)                                Abort a run, reset run number
ADD       in1 in2 out                  Add two images to give third
ARCH(IVE) first last                   Archive runs to tape
BIA(S)                                 Synonym for NEW_BIAS
BIN       nx ny                        Bins data into groups of pixels
```

CAD(D)	n in out	Add scalar to image
CCDIN(IT)		Complete re-initialise
CCDSPACE		Check space left on disk
CDI(V)	n in out	Divide image by scalar
CH(IP)	chip	Set new chip
CLE(AR)		Clear the chip
CLO(SE)		Close shutter
CLOV(ER)		Clear Lexidata overlay planes
CMU(LT)	n in out	Multiply image by scalar
COMM(ENT)		Insert comments into file
CONT(INUE)		Continue a paused run
COPY	in out	Copy image to new file
CSU(B)	n in out	Subtract scalar from image
DAT(A)	d/t n	Redefine the dump device
DEF_W(INDOW)		Reset window to default values
DEPROTECT		Deprotect the glance file
DESC(RIPT)		Read, write, delete descriptors
DIP(ARM)	option low high	Alter display parameters
DIS(P)	defaulted	Display image on Lexidata
DIV	in1 in2 out	Divide two images
ENQ_BIAS		Display current bias estimate
ENQ_DUMPDEV		Display current dump device
ENQ_FLASH		Display pre-flash time
ENQ_NUMRUN		Display run number
ENQ_OBSERVER		Display initials of observer
ENQ_TIME		Display current integration time
EXPO(SE)	time	Perform exposure
EXTR(ACT)	in x1 x2 y1 y2 out	Extract sub-image
FF	respond to prompts	Flat fields an image
FILES n1 n2		Inquire status of runs n1 to n2
FILT(ER)	number	Select filter
FITSDIR	respond to prompts	List contents of FITS tape
FITSIN	respond to prompts	Read FITS file from tape to disk
FITSINIT	respond to prompts	Prepare FITS tape for use
FITSOUT	respond to prompts	Write FITS file from disk to tape
FLA(SH)		Do pre-flash
FOC(US)		Focus CCD
FOCUSCONTINUE		Continue with focus of CCD
GLA(NCE)	time	Perform quick look run
GMV(AR)	variable	Get microcode variable
GO		Start a run after PREPARE
HELP CCD	topics	Give help on the CCD commands
INSP(ECT)		List image contents
IPC(S)		Load IPCS control program
KEE(P)	object	Save GLANCE file as run file
KILL	IPCS	Delete IPCS control program

KILLMULT(RUN)	Abort exposures started by MULTRUN
LCS	Load control store
LEXCL(EAR)	Clear / reset Lexidata
LEXINI(T)	Initialise the Lexidata
LEXPA(N)	Zoom / pan Lexidata
LEXZOO(M) xcent ycent factor	Zoom Lexidata
LOADEM	Load IPCS external memory
LRC(CS)	Load, Read, Check control store
LUTCON(TRAST)	Alter LUT contrast
LUT(LOAD) lut	Load LUT
LUTROT(ATE)	Rotate LUT
MANI(C)	Image manipulation
MATH(S)	Image arithmetic
MCS address value	Modify control store
MUL(T) in1 in2 out	Multiply two images
MULTEXP n t d	n exposures of t secs in direct d
MULTRUN n t c	n runs of t secs on object c
NEW_BIAS	Set new bias estimate
NEW_DUMPDEV	Set new dump device
NEW_FLASH	Set new pre flash time
NEW_NUMRUN	Set new run number
NEW_OBJECT	Set new object name
NEW_OBSERVER	Set new initials for observer
NEW_TIME	Set new integration time
NEXTR(UN) number	Set next run number
NOCL(EAR)	Prevent CLEAR on next run
NODISP =n	0 display, 1 not display image
NOPACKETS =1	Turn off packets.
NOPACKETS =0	Turn on packets.
NOTIMES	Turn off listing of timing info
OBSN(AME) name	Set new observer's initials
OP(EN)	Open shutter
PACKETS	Write packets to current image
PA(USE)	Pause an active run
PEE(P) respond to prompts	List a part of an image
PHOT(OM) defaulted	Simple photometry program
PLOT respond to prompts	Plot on Lexidata / T4010
PLOTLP respond to prompts	Plot on Printronix Line-printer
PREFLASHDEFAULT =n	Sets default pre-flash to n
PREPARE time object	Sets up d-task to do a run
PURGE respond to prompts	Purge run files from disk
QBIAS	Synonym for ENQ_BIAS
QCH(IP)	Identify current chip
QDI(PARM)	List display parameters
QFI(LES)	List current files etc
QFLA(SH)	List current flash time

```
QMO(DE)                                List observing mode
QU(IT)                                 CLosedown CCD and exit
QWIN(DOW)                              List current window
RCS                                    Read control store
REA(D)     file                        Read out chip
REC(ALL)   number                      Make old run current image
RES(ETCCD)                             Initialise CCD controller
RESTART                                Software reset of CCD controller
RFILE                                  Allocate next run file
RU(N)      time object                 Perform standard run
RUNSTAT(US)                            List run status
SEND       CON:                        Break in on ADAM
SETFL(ASH) time                        Set up pre-flash time
SHOWTIMES                              Display timing info for a run
SHUTDOWN                               Shut down ADAM system
SMV(AR)    variable value              Set microcode variable
SPECD(ISP)                             IPCS spectral display program
SQEL       in out dirn xy1 xy2         Add rows or columns
STATS      image                       Calculate image statistics
STO(P)                                 Stop a run
STO(RE)    runid storeid               Store run in store file
SUB        in1 in2 out                 Subtract one image from another
TAP(E)                                 Write current image to tape
TEL(E)     defaulted                   List telemetry values
TESTCCD                                Clears chip, tests telemetry
TILT                                   Check tilt of CCD
TIM(E)     time                        Alter exposure time of current run
UNZ(OOM)                               Unzoom Lexidata
VERIFY                                 Alter/set tape dump verification
WIN(DOW)   xstart ystart xsize ysize   Set new readout window
```

5.7.2 FITS

All data is written to tape at 1600 bpi in FITS format. The available commands that follow can be obtained on-line by typing HELP FITS COMMANDS SUMMARY

```
FILE_NAMES            Describes the filename conventions used in ADAM
FITSCOPY              Used to copy all or part of one FITS tape to another
FITSDIR               To list the contents (descriptors) of a FITS tape
FITSIN                To copy files from a FITS tape to disc
FITSINIT              To initialise/position a FITS tape
FITSOUT               To copy files from disc to a FITS tape
```

5.7.3 ADAM Command Language

A glossary of ACL can be obtained on-line by typing HELP ACL SUMMARY

ACTIVE	Test if an ACL stream is active
ALLOCATE	Allocate files with given characteristics
BATCH	Execute a file of ADAM commands
Break-in	How to interrupt ADAM
DCL	Declare an ACL variable
DECLARE	Declare an ACL variable
DEFINE	Define and A- or D-task
DELETE	Delete files
DO	Delimit start of DO loop
ELSE	Delimit alternatives in IF structures
END	Terminate DO, IF or PROCEDURE
EPRINT	Write error message to ADAM terminal
EXIT	Return procedure execution to ACL
Expressions	Legal expressions within the ACL
FORGET	Delete variables or dictionary entries
GET	Load the dictionary from a file
HOLD	Suspend execution of an ACL stream
IF	Delimit start of an IF expression
INQUIRE	Inquire after characteristics of files
IPRINT	Write informational message to ADAM terminal
KILL	Abort a task or procedure run by ACL
LET	Make assignment to an ACL variable (use =)
PRINT	Write message to ADAM terminal
PROCEDURE	Delimit start of PROCEDURE definitiion
Pseudo_variables	A useful adjunct to the variable system
PUT	Copy the current dictionary to a file
QUIT	Terminate ACL
RELEASE	Release a suspended ACL stream
REPROTECT	Change the write protection key of files
SEND	Send request to an active D-task
SET	Set certain ACL system quantities
SHOW	Show certain ACL system quantities
STREAM	Start an ACL stream
SYCHRONIZE	Synchronize with another ACL stream (wait for it)
WAIT	Suspend issuing ACL stream for a period of time
WPRINT	Write warning message to ADAM terminal

Extra ACL information

Some extra information is available in the ACL_FACILITIES SUMMARY

ACCEPT	Command to accept input from the user
BLANK	Command to test if a character string is BLANK
COMMAND	Command to prompt user for a response
CONCAT	Concat to concatenate two character strings
HELP	The ADAM HELP utility

5.7.4 Lexidata

HELP LEXIDATA SUMMARY gives a glossary of the programs that can be used to display data or give commands to the Lexidata image display device.

CONTRAST	Changes the contrast of the dispayed image
DISP	Displays an image on the Lexidata
LEXCLEAR	Clears the Lexidata display
LEXINIT	Initialises and clears the Lexidata
LUT <name>	Loads a lookup table <name> can be COLS of GREY
PAN	Pans the image under joystick control
PHOTON	Gives profiles, statistics etc. of an image
ROTATE	Rotates the current lookup table
ZOOM	Expands the image about a given point

5.7.5 Utilities

A summary of the utility commands available is given by HELP UTIL SUMMARY

CHFORM	A-task to change format of an image file
DESCR	A-task to list the FITS descriptors in an image file
FITS	A-tasks to read/write/list FITS tapes
IMAGPLOT	A-task to print image files on lineprinter
LEXPLOT	A-task to print LEXIDATA memory on lineprinter
PLOT	A-task to display a 1-d slice on a graphics device
PLOTLP	A-task to plot a 1-d slice on lineprinter
SQUISH	A-task to alter shape of an image file

STATS	A-task to analyse an image file
VERIFY	A-task to compare two image files

5.7.6 Telescope control

HELP TCS SUMMARY gives a glossary of those commands applicable to the INT Telescope control user interface.

.SOURCE	Defines a new entry in resident catalog
*	What follows is treated as a comment
ACQUISITION-MODE	Defines the autoguider aquisition mode
ADAM	Help on ADAM and Instrument Control System
ADVISE	Lists certain info about a source
APERTURE	Sets up the aperture offsets
APPARENT	Use geocentric apparent coordinates for edit. sources
AUTOFFSET	
CLEAR	Clears source entries from resident catalog
CURRENT	Nominates edit source as current source
DEC	Enters declination for edit source
DIFFERENTIAL-RATE	Sets up differential tracking rates
ENABLE	Pre-requisite for certain other commands
END	Terminates input from device/file
EQUINOX	Sets up the equinox for edit sources
FOCUS	Sets the telescope focus
GO	Slews telescope to next source and tracks
GUIDE-OBJECT	Defines guide object for edit source
HANDSET	Sets up set and guide rates and increment step
HELP	Description of the HELP command/facility
INPUT	Specifies input source of commands (device/file)
LIST	List the sources in the resident catalog
MEAN	Use mean coordinates for edit sources
NEXT	Defines the next source to be observed
OFFSET	Sets up the telescope offsets
PROCEDURES	
PROPER-MOTION	Sets the proper motion of the edit source
RA	Enters Right Ascension for edit source
REPORT	Switches to a report mode
SAVE	Saves the resident catalog in a file
SCAN	Sets up raster scan parameters
SET	Sets several system flags
SHOW	Lists parameters of a specified source
SNAFU	Sets up collimation and index errors and aperture offsets

STATUS	Gives the size of the resident catalog
STOP	Stops the telescope and dome
TELESCOPE	Reports all/selection of telescope parameters
TITLE	Prints line of info from input file
TRAIL	Sets up parameters for a trail
TURNTABLE	Moves the INT CASS rotator
WAIT	Waits for a specified period
ZEROSET	Zerosets the incremental encoders

5.7.7 Spectrograph commands

HELP SPEC SUMMARY gives those commands applicable to the INT IDS which are available for the observer.

AGSPDIAG		Turn on/off diagnostics for selected mechanisms
AGSPINIT		Initialise the A&G Box/IDS software
AGSPLOAD		Load the A&G Box/IDS D-task
ARCF		Allocate the next TV archive file
BSCF	n	Move the Below Slit Colour Slide to pos n (0 to 2)
BSND	n	Move the Below Slit ND Slide to pos n (0 to 2)
CENWAVE	lambda	Ask IDS to move grating to give requested wavelength
CHANCE		Setup certain A&G Box/IDS h/w characteristics
COLLIMATOR	pos	Move the collimator to position pos (108 to 277)
DEKKER	pos	Move the Dekker to position pos (0 to 8)
Engineering		Engineering level information
ENQ_ARCNUM		Ask for current TV archive file number
EXGRAT		Special grating command to increase encoder accuracy
EXORCET		Description of Engineer's controller
GET_GRAT_ZERO		Displays the current grating encoder zero point
GLIGHT	val	Turn grating light ON or OFF
GRATING	angle	Move the grating to a given angle (11 to 169 deg)
GRAT_ZERO	theta	Sets the grating encoder zero point to theta degrees
GSMOVE	pos	Move the grating shutter to OPEN or CLOSE
HARTMANN	l r	Move l(eft) and r(ight) Hartmanns IN or OUT
IDSCAMERA	pos	Move the camera shutter to OPEN or CLOSE
IDSENG	comm	Send a primitive command to the IDS micro
IDSSTAT		Ask for status from all IDS mechanisms
ILLUMOFF		Turn off grating and slit illumination
IOPROCEED	0/1	Turn mechanism wait flag ON or OFF
IPL		The Inter Processor Link
LISTSTATUS		List the A&G Box/IDS status on the ADAM terminal
MIMIC		The A&G Box/IDS mimic task
NEW_ARCNUM	n	Set the current TV archive file number to n
PANIC_BUTTON		Describes the effect of pushing the RED PANIC BUTTON

parameters		Some parameters defined for the user
QDEKKER		Display the characteristics of the loaded Dekker
QFILTER		Display the contents of A&G Box/IDS filter slides
SHUTDOWN		Shutdown the A&G Box/IDS s/w in a safe and orderly manner
SHUTTER	pos	Move the slit shutter to OPEN or CLOSE
SHUTTERPROMPT	pos	Move the slit shutter to OPEN or CLOSE but prompt
SLIGHT	val	Set the slit illumination (0 to 15)
SLITJAW	val	Move slit width to val microns (25 5o 2000)
SPECSTAT		Ask for status from all IDS mechanisms
STARTMIMIC		The only correct way to start/restart the MIMIC task
SWAP		Swap position of the Hartmann screens
SWAP_CAM		Swap camera identification
TVDIAG	val	Turn TV system READ and WRITE diagnostics ON or OFF
TVRDIAG	val	Turn TV system READ diagnostics ON or OFF
TVS		The Grinnell TV System
TVWDIAG	val	Turn TV system WRITE diagnostics ON or OFF
TV_DISPFZ		Request dispaly of Finder zero point from D-task
TV_GETFZ		Request Finder zero point from TVS display
TV_GLOBAL		Send Global Status to TV system
TV_SETFZ	x y	Set Finder zero point held by TVS

5.7.8 A&G box

Those commands applicable to the INT A&G box which are available to the observer can be obtained by HELP AGBX SUMMARY

AFARC	n	Move Arc filter wheel A to position n (0 to 7)
AGBENG	comm	Send a primitive command to the A&G Box micro
AGBXSTAT		Ask for status from all A&G Box mechanisms
AGSPDIAG		Turn on/off diagnostics for selected mechanisms
AGSPINIT		Initialise the A&G Box/IDS software
AGSPLOAD		Load the A&G Box D-task
ARCF		Allocate the next TV archive file
ARCS_OFF		Turn off all arc lamps in the integrating sphere
ASCF	n	Move the Above Slit Colour Slide to pos n (0 to 5)
ASND	n	Move the Above Slit ND Slide to pos n (0 to 5)
BFARC	n	Move Arc filter wheel B to position n (0 to 7)
CALMIRROR	pos	Old version of COMPMIRROR command
CENTRE	probe	Move the TV/Guider probe to centre position
CHANGE		Setup certain A&G Box h/w characteristics
COMPMIRROR	pos	Move the calibration mirror IN or OUT
CUAR	state	No longer available - use 1LAMP or 2LAMP
CUNE	state	No longer available - use 1LAMP or 2LAMP

Engineering		Engineering level information
ENQ_ARCNUM		Ask for current TV archive file number
EXORCET		Description of Engineer's controller
FGRATICULE	val	Set field graticule illumination
FLIPMIRROR	pos	Move the flip mirror IN or OUT
GDFILTER	n	Move the Guider filter slide to pos n (0 to 3)
GDXY	xpos ypos	Move the Guider probe to position (xpos, ypos)
IOPROCEED	0/1	Turn mechanism wait flag ON or OFF
IPL		The Inter Processor Link
LISTSTATUS		List the A&G Box status on the ADAM terminal
MIMIC		The A&G Box mimic task
NDFARC	nd	Move the A/B Arc filter wheels to give this ND
NEW_ARCNUM	n	Set the current TV archive file number to n
PANIC_BUTTON		Describes the effect of pushing the RED PANIC BUTTON
parameters		Some parameters defined for the user
PARK	probe	Move the TV/Guider probe to parked position
QFILTER		Display the contents of all A&G Box filter slides
SHUTDOWN		Shutdown the A&G Box s/w in a safe and orderly manner
STARTMIMIC		The only correct way to start/restart the MIMIC task
TUNGSTEN	state	To turn the tungsten lamp ON or OFF
TVDIAG	val	Turn TV system READ and WRITE diagnostics ON or OFF
TVFILTER	n	Move the TV filter slide to pos n (0 to 3)
TVRDIAG		Turn TV system READ diagnostics ON or OFF
TVS		The Grinnell TV System
TVWDIAG		Turn TV system WRITE diagnostics ON or OFF
TVXY	xpos ypos	Move the TV probe to position (xpos, ypos)
TV_DISPFZ		Request display of Finder zero point from D-task
TV_GETFZ		Request Finder zero point from TVS & display
TV_GLOBAL		Send Global Status to TV system
TV_SETFZ	x y	Set Finder zero point held by TVS
1LAMP	state	To turn the lamp in slot 1 ON or OFF
2LAMP	state	To turn the lamp in slot 2 ON or OFF

Appendix A

Flux Standards

With the proliferation of linear detectors on Cassegrain spectrographs, spectrophotometry has become a common byproduct of many spectroscopic observations. The cornerstone of such studies is the system of spectrophotometric standards. Useful references are:

Filippenko, A.V., Greenstein, J.L., 1984. *Publ. astr. Soc. Pacif.* , **96**, 530

Oke, J.B., Gunn, J.E., 1983. *Astrophys. J.* , **266**, 713

Massey *et al.* , 1988. *Astrophys. J.* , **328**, 315

For observers with access to a STARLINK node, the main Figaro directory (logical name FIGARO_PROG_S) contains a number of files, including those recently compiled by Roderick Johnstone (IoA) giving the published flux densities of standard stars, all with a .TAB extension according to FIGARO convention.

The VMS DIRectory command may be used to find which files are available as tables. The command

```
$DIR FIGARO_PROG_S:*.TAB
```

will list all the table files supplied in the main directory. Not all of these are intended for flux calibration; some may be extinction tables, etc. These are all text files, and have comments at the start describing their function. For most of the flux standards for which Figaro supplies tables, two tables are provided: one in AB magnitudes, usually a direct copy of the published data, and one in (milli- or micro-) Janskys, usually the result of a semi-automatic conversion from the former. If you particularly like $ergs\ s^{-1}\ cm^{-2}\ \text{Å}^{-1}$, then you can either provide your own flux tables in these units and work from them directly, or you can use the FLCONV command to convert from a spectrum calibrated in Janskys into these units.

The command

```
$TYPE FIGARO_PROG_S:file.TAB
```

will list the file. For example, the file G158M100.TAB begins as follows -

```
*                   G 1 5 8 - 1 0 0
*
*   Table file for G158-100, faint object flux standard,
*   based on Filippenko and Greenstein (1984) P.A.S.P.
*   96, 530. Note that these are fitted continuum
*   fluxes, not directly measured fluxes, and should
*   be used accordingly.   This file is designed for
*   use with the Figaro routine GSPIKE.  The data here is
*   given to 3 decimal places and was supplied directly by
*   Alex Filippenko.
*
SET .Z.UNITS = "micro-Janskys"
SET .Z.LABEL = "Flux"
*
 3300   891.251
 3400   990.831
 3500  1135.534
 3600  1282.331
 3700  1432.187
 3800  1599.556
 3900  1770.110
```

The lines beginning with asterisks are treated as comments, and the lines that begin with 'SET' are used to set data objects in the file created from this table.

An alternative version of this file is G158M100A.TAB, the A added after the star name indicates that the list is in AB magnitudes. It contains the lines

```
SET .Z.UNITS = "AB Magnitudes"
SET .Z.LABEL = "Flux"
SET .Z.REVSCALE = 1
SET .Z.MAGFLAG = 1
*
 3300   16.525
 3400   16.410
 3500   16.262
 3600   16.130
 3700   16.010
 3800   15.890
```

The functions of the .Z.UNITS and .Z.LABEL lines should be fairly obvious. Setting .Z.REVSCALE to 1 in a file indicates to SPLOT that the data should be plotted with the flux scale reversed, and setting .Z.MAGFLAG indicates that the scale is in logarithmic units. Tables based on data from, for example, Oke and Gunn's 1983 paper will also include the line

SET .Z.BANDWIDTH = 40

to indicate the 40 Angstrom bandwidth used by their data. The Filippenko and Greenstein data represents fitted continuum fluxes, so does not have a bandwidth. From the .TAB files already supplied, it should be possible for you to deduce how to create your own, should that be necessary.

Table 1 lists the stars available in FIGARO main directory (Column 1), name of the file (Column 2), wavelength coverage (Column 3) and comments (Column 4).

The files listed contain stellar fluxes in milli-janskys. AB magnitude files have the same name, but with an A after the star's name. Files are called after the star with + and - signs replaced by P and M respectively. Some files have been included more than once under aliases of the star name.

Numerical values of wavelength, flux, bandwidth and order changeover wavelengths have been checked and are believed to be correct.

Note that there are several different magnitude systems which determine the fluxes presented in these tables. These are defined through different calibrations of the primary standard Vega and use different ways of transferring the magnitude system from Vega to the fainter secondary standards. In general the stars listed here are not actual standards but are just good calibrations of non-variable stars. The user is strongly advised to read the paper from which the numbers come (listed at the top of each file) to gain an idea of both the random and the systematic errors in the fluxes as well as the magnitude system from which the fluxes derived.

Special thanks to Doreen Oliver at RGO who typed in most of the original files and to Carolyn Crawford who gave invaluable help checking the numbers.

```
Star           File           Coverage       Comments
====           ====           ========       ========

40 Eri B       40ERIB.TAB     3320-9880
AM CVn         HZ29.TAB       3340-8720
BD+25 3941     BDP253941.TAB  3200-8370
BD+28 4211     BDP284211.TAB  3200-8370
BD+33 2642     BDP332642.TAB  3200-8370
BD+40 4032     BDP404032.TAB  3200-8370
BD+82 2015     BDP82015.TAB   3200-8370
EG  5          VMA2.TAB       3260-10640     Used 2nd order
                                             values at overlap
EG 11          L870M2.TAB     3210-7220
EG 28          LB1240.TAB     3210-7220
EG 29          LB227.TAB      3210-7220
EG 31          HZ2.TAB        3210-7220
EG 33          40ERIB.TAB     3320-9880
EG 39          HZ7.TAB        3210-7220
EG 42          HZ14.TAB       3230-7420
EG 50          HE3.TAB        3340-9440
```

EG 54	L745M46AA.TAB	3320-10520	Cosmetic change to lambda_double
EG 63	LDS235B.TAB	3320-8920	Cosmetic change to lambda_double
EG 67	SA29M130.TAB	3210-10200	
EG 76	AL970M30.TAB	3180-7040	40A bins in 2nd order
EG 76	BL970M30.TAB	3320-9880	80A bins in 2nd order
EG 77	TON573.TAB	3340-8160	
EG 79	R627.TAB	3160-10840	
EG 86	HZ21.TAB	3340-9660	
EG 91	HZ29.TAB	3340-8720	
EG 98	HZ43.TAB	3320-10520	
EG 99	W485A.TAB	3320-9880	
EG 102	GRWP705824.TAB	3210-10200	
EG 119	ROSS640.TAB	3320-10520	
EG 129	GRWP708247.TAB	3340-9200	
EG 133	L1573M31.TAB	3336-10073	
EG 139	W1346.TAB	3210-10640	
EG 144	GRWP738031.TAB	3340-9440	
EG 148	L1363M3.TAB	3316-10520	
EG 149	L930M80.TAB	3320-9240	Cosmetic change to lambda_double and correct value at 4510
EG 162	L1512M34B.TAB	3210-10040	
EG 182	G47M18.TAB	3340-9280	
EG 184	GD140.TAB	3160-10560	
EG 192	AGD185.TAB	3200-7240	80A bins 2nd order
EG 192	BGD185.TAB	5820-9780	360A bins
EG 247	G191B2B.TAB	3320-10520	
Feige 110	F110.TAB	3200-8370	_S: file seems to have wrong bandwidth and lambda_double
Feige 15	F15.TAB	3200-8370	
Feige 25	F25.TAB	3200-8370	
Feige 34	F34.TAB	3200-8370	
Feige 56	F56.TAB	3200-8370	
Feige 92	F92.TAB	3200-8370	
Feige 98	F98.TAB	3200-8370	
G191B2B	G191B2B.TAB	3320-10520	
G47-18	G47M18.TAB	3340-9280	
GD 140	GD140.TAB	3160-10560	
GD 185	AGD185.TAB	3200-7240	80A bins 2nd order
GD 185	BGD185.TAB	5820-9780	360A bins
GD-248	GDM248.TAB	3300-10000	Not from SPICA
Grw+70 5824	GRWP705824.TAB	3210-10200	
Grw+70 8247	GRWP708247.TAB	3340-9200	

Grw+73 8031	GRWP738031.TAB	3340-9440	
He 3	HE3.TAB	3340-9440	
HZ 14	HZ14.TAB	3230-7420	
HZ 15	HZ15.TAB	3200-8370	
HZ 2	HZ2.TAB	3210-7220	
HZ 21	HZ21.TAB	3340-9660	
HZ 29	HZ29.TAB	3340-8720	
HZ 43	HZ43.TAB	3320-10520	
HZ 44	HZ44.TAB	3316-10520	Ambiguity in bandwidth at changeover to first order
HZ 7	HZ7.TAB	3210-7220	
Kopff 27	KOP27.TAB	3200-8370	
L1363-3	L1363M3.TAB	3316-10520	
L1403-49	TON573.TAB	3340-8160	
L1512-34B	L1512M34B.TAB	3210-10040	
L1573-31	L1573M31.TAB	3336-10073	
L745-46A	L745M46AA.TAB	3320-10520	Cosmetic change to lambda_double
L870-2	L870M2.TAB	3210-7220	
L930-80	L930M80.TAB	3320-9240	Cosmetic change to lambda_double and correct value at 4510
L970-30	AL970M30.TAB	3180-7040	40A bins in 2nd order
L970-30	BL970M30.TAB	3320-9880	80A bins in 2nd order
LB1240	LB1240.TAB	3210-7220	
LB227	LB227.TAB	3210-7220	
LDS235B	LDS235B.TAB	3320-8920	Cosmetic change to lambda_double
R627	R627.TAB	3160-10840	
Ross 640	ROSS640.TAB	3320-10520	
SA29-130	SA29M130.TAB	3210-10200	
Ton573	TON573.TAB	3340-8160	
VMa 2	VMA2.TAB	3260-10640	Used 2nd order values at overlap
W1346	W1346.TAB	3210-10640	
W485A	W485A.TAB	3320-9880	

Table 2 has been compiled for the WHT manual by Janet Sinclair (RGO) and includes 1950.0 positions, proper motions, m_{5556} and spectral type of spectrophotometric standards.

r

r

r

Appendix B

Data Reduction

We hesitate to include this appendix, because we realize that probably there are as many ways of reducing data as CCD users in the astronomical comunity.

We would like anyway to make some general comments, based on our personal experience, for the benefit of first time users.

B.1 Data format

The observer takes home a copy of the data tapes, that has been produced in FITS format. The original D-tape is archived at RGO. The header information on the data is kept on-line on a Vax computer, and can be accessed using the La Palma Data Archive (E.J. Zuidewijk, 1989, Technical Note # 69) by the owner and, after one year, by anyone interested in the data.

Prior to 16/1/1989, the data from the CCD was copied into tape as produced: unsigned 16 bit. FITS data conventions are unsigned 8 bit; signed 16 bit and signed 32 bit. STARLINK FITS routines therefore considered the data as supported by the conventions which is fine for count values in the range 0 to $(2^{15}-1)$=32767. For output in the range $(2^{15}-1)$ to $(2^{16}-1)$ the routines would produce negative numbers in the range -2^{15} to -1. This data looks as if it is saturated. The simplest recipe is to search for negative numbers, and add to them $2^{16}=65536$. This is done by simple routines available in STARLINK.

Changes have been introduced to handle CCD data at the telescope in a consistent and correct manner. After the 16/1/1989, CCD images created on the INT are labelled internally on disc as U2 (unsigned 16 bit) and FITS tapes now conform exactly to the international FITS standard.

B.2 Bias

You would have obtained during the night (read again Chapter 4) several frames with no illumination to determine the modulations of the "zero" level, or dark current, across the chip. This zero level also changes during the night, so we find convenient to use the underscan columns for each frame (1-11 in the GEC CCDs) to determine it.

We proceed as follows:

1. Average all the bias frames and smooth them slightly (e.g. top-hat 3 pixels).
2. Check for – and eliminate – hot spots.
3. Trim the four edges to get rid of rubbish that will otherwise ruin your mean values, but taking care to leave some of the underscan columns (columns 7-10 is usually enough; 1-4 after trimming). The dark level for each frame is to be obtained from them.
4. Subtract the mean value of the whole frame to obtain a new frame with the modulations and a mean value of $\sim$ zero. This we will call, in what follows, the bias frame.

B.3 Preflash

If the chip used needed preflash, you would have obtained some preflash frames at the beginning and end of the night, plus one or two flash maps (see Chapter 4).

1. Average the flash maps.
2. Check for – and eliminate – hot spots. Smooth the frame.
3. Trim the edges to the same size of the bias frame.
4. Obtain the mean value of the dark current from the underscan columns (now 1-4, for example) and add that number to the bias frame.
5. Subtract the resulting frame from the one obtained after step 3.

Proceed likewise with the preflash frames. The ratio of mean values of these two frames should be similar to the ratio of flash units used. You can divide the flash map by this ratio and use this "scaled" preflash as the one to subtract from the data frames. Use the preflash frames to check for consistency.

B.4 Flat field

You can repeat steps 1-5 from B.3 using the flat field frames; this time without smoothing as you are interested in the pixel to pixel variations. Then subtract the "scaled" preflash (if used) from the resulting frame. You will have obtained a flat field frame; divide it by its mean value and you have a normalized flat field that is now ready to be used in the data reduction.

For extended objects, it is important to obtain during twighlight several well exposed ($\sim 10^4$ counts) sky frames, because the illumination of the slit by a lamp might not be uniform. These flat skies are reduced as flat fields.

B.5 Objects

You have finished now preparing the "initial" frames (bias, preflash and flat field) for the reduction of one night's objects. You might have different flat fields for each telescope configuration.

Object by object you can proceed as follows:

1. Check for – and eliminate – hot spots.
2. Trim the edges to the same size of the bias frame.
3. Obtain the mean value of the dark current from the underscan columns (now 1-4, for example) and add that number to the bias frame.
4. Subtract the resulting frame from the one obtained after step 3.
5. Subtract the "scaled" preflash (if used).
6. Divide by the normalized flat field.

Calibration frames are treated as objects.

B.6 Calibrations

It is important to prepare your calibration tactics before your observing trip. These preparations include

a) Selecting the lamps to use at each telescope configuration (see Appendix C).

b) Selecting the stars to correct for atmospheric absorptions (F8 stars make good calibrators).

c) Selecting the flux standards to use (see Appendix A).

Back home after your trip, and after steps B.1 to B.5 of the reduction, you will be able to use your favourite calibration package. FIGARO, for instance, allows you to calibrate in wavelength in 2-D which is very useful, specially if you are working with extended objects. You can then extract 1-D spectra and 1-D sky to subtract, and you will be ready to eliminate atmospheric absorptions, calibrate in flux and write your papers.

Appendix C

Calibration Arcs

"A Spectral Atlas of calibration lamps in use with IDS" (E.J.Zuiderwijk and J.Knapen 1989) is being issued by RGO. It contains maps of a Cu-Ar arc with high, intermediate and low dispersion (1200, 400 and 150 lines mm^{-1} gratings), Cu-Ne with high and low dispersion (1200 and 150 lines mm^{-1} gratings), Th-Ar with high dispersion (1200 lines mm^{-1} grating), Cu-He with low dispersion (150 lines mm^{-1} grating) and Al/Ca/Mg-Ne with intermediate dispersion (632 lines mm^{-1} grating).

The main features of the different lamps are described also here, so that users can decide which lamps are more adequate for their observations. Some of the comments that follow, only apply to CCD observations and not to IPCS ones, due to the difference in dynamic range between both detectors. The best way to judge is actually by inspecting the arc atlas.

C.1 Comparison lamps

Several lamps are available in the INT A&G unit for wavelength calibration. Two lamps are allowed to be simultaneously used, and they are by default Copper-Argon in position 1 and Copper-Neon in position 2. Users wanting a different one should specify their requirements in advance so that the lamp is installed by the duty technician in place of the standard ones.

C.1.1 Cu-Ar lamp

The Copper-Argon lamp presently in use with the IDS shows only ArI and ArII spectra. Copper lines are not seen. It shows two distinct spectral regions:

1. Between 3900 Å and 6965 Å the spectrum contains a large number of relatively faint lines, which can be used in both low and high dispersion work. The region 3900 Å to 5100 Å is particularly useful both with CCD and IPCS detectors. Between 5200 Å and 5500 Å, although there are a large number of lines, they are comparatively weak and large exposure times are needed. One may be better off with the Th-Ar lamp for this region.

2. Redwards of 6965 Å up to 9784 Å, the spectrum contains a large number of strong and very strong emission lines, which give the argon arc its characteristic red colour. However between these strong lines there are gaps devoid of even very weak lines, particularly redwards of 7500 Å. There the spectrum is only useful at low dispersion (150, 300 and 400 g/mm gratings) or at high dispersion, in combination with another lamp (e.g. Cu-Ne).

This lamp is normally located in position 1, enabled by the Adam command 1LAMP ON.

C.1.2 Cu-Ne lamp

The Neon spectrum between 3100 Å and 9600 Å can be roughly divided in three sections: very strong features due to NeI dominate the wavelength range 5850-7440 Å; another group of prominent features are present between 7500 and 9600 Å, although these are as much as ten times fainter than those in the former range. Bluewards, neon lines, both NeI and NeII, appear only weakly, and the copper spectrum provides the strongest features. Even so, the strong copper line CuI λ 5105 Å is barely one-twentieth the intensity of the principal NeI lines described earlier.

This implies that for wavelength calibrations in the red, the copper-neon lamp is only really useful for low-dispersion work whilst the red features are so spaced that at high dispersion very few lines may be present in certain wavelength intervals. In the blue, at intermediate and high dispersions, it may be useful to supplement the argon spectrum in regions where this is a bit sparse e.g. 3300-4000 Å, but significantly longer exposures would be necessary to bring up the few NeII lines below 3250 Å. To reach a few weaker lines redward of 9700 Å, in particular in the region 1.0–1.1μm, careful second-order filtering is required, and also considerable patience.

This lamp is normally located in position 2, enabled by the ADAM command 2LAMP ON.

C.1.3 Th-Ar lamp

This lamp gives a very rich emission line spectrum over a wide wavelength range and is thus very useful for high dispersion work, particularly in the red where the Cu-Ar and Cu-Ne ones are rather sparse. Our lamp produces very weak lines to the red of 7200 Å and long exposures are required which will produce the undesirable effect of overexposing the very strong Argon features. On the other hand, it is not recommended for medium and low dispersion work because of the severe problems which line-blending would introduce.

This is not a standard lamp, so users must notify their SA in advance for the lamp to be installed.

C.1.4 Cu-He lamp

The spectrum is that of pure HeI with some contamination by very weak hydrogen; copper lines are not seen.

Between 3800 Å and 5050 Å it has 12 well defined lines which makes it useful at low dispersion. Between 5875 Å and 7281 Å the spectrum contains 4 strong emission lines, while beyond 7282 Å only a few weak lines are present. The only strong feature in the far red is the line at λ 10830.3 Å. Apart from this far red line, the lamp could be useful in combination with another one to fill gaps (e.g. Cu-Ar) or for very low dispersion spectroscopy with FOS.

This is not a standard lamp, so users must notify their SA in advance for it to be installed.

C.1.5 Al/Ca/Mg-Ne lamp

This lamp was originally acquired for the wavelength calibration of TAURUS data. The spectrum contains, apart from the NeI features, a large number of multiplets of CaI, MgI and AlI, which dominate the blue spectral range. In the far red, some of these multiplets neatly fill gaps between the NeI lines. This lamp is useful at high dispersion CCD work in narrow selected regions.

Appendix D

Filters, gratings and masks

D.1 Filter sets

Neutral density and colour filters are available to use either above or below the spectrograph slit.

Order sorting filters

The standard ASCF (above slit colour filter) has 6 positions that correspond to

Position	Filter
0	Clear
1	WG360
2	GG495
3	RG630
4	BG38
5	GG385

These are general order sorting filters or other λ discrimination. Figure 2.5 gives their wavelength dependent transmission. All filters are 2mm thick with selective antireflection coatings added.

A non-standard slide (ASCF #0) is available for users to request special setups. The slide can accomodate 5 standard-size filters (45mm by 60mm by 3mm) or 4 standard-size filters plus one 50mm diameter which requires a special mounting to insert it into the tray. Users may provide their own filters in advance for an observing session, to be mounted on this slide by local support.

The slide BSCF (below slit colour filter) can carry filters in positions 1 and 2, 0 is clear. If you use below slit filters, the collimator has to be moved to account for the change in the optical path length.

Neutral density filters

The above slit neutral density filters are put in position by issuing the ADAM command ASND n, where n, valued from 0-5 corresponds to

Position	Filter
0	Clear
1	0.3
2	0.6
3	1.2
4	1.8
5	3.0

Calibration lamp filters

Two filter wheels (A and B) are available for the calibration lamps. AFARC n and BFARC m put in position n and m the filters in wheels A and B; n and m are numbers between 0 and 7 corresponding to

Position	AFARC	BFARC
0	Clear	Clear
1	0.236	0.33
2	0.61	0.498
3	0.80	0.89
4	1.74	1.20
5	3.0	2.1
6	empty at	empty at
7	present	present

Wheels A and B are used together in any combination, giving a density range between clear and 5.10. By specifying ND x the software will choose the combination of A and B equal or greater than x.

D.2 Gratings

The gratings available for use with the IDS are given in Tables 3.1 and 3.2, and their efficiency as a function of wavelength, in Figure 2.4.

The R or H prefix in the name of the grating indicates whether it is conventionally ruled (R) or "holographic" (H). The number indicates the frequency of groves/mm. And the last letter refers to the region of the spectrum where maximum efficiency occurs.

Graphs of grating settings are given in Dataset 5 of the IPCS Cook Book.

D.3 Dekker masks

Dekker masks with the CCD are normally used only for set-ups and in the clear (0) position. The default is the IPCS dekker mask. It has 9 positions corresponding to

Position	arcsec	mm
0	Clear	Clear
1	0.5	0.10
2	1.0	0.18
3	1.5	0.32
4	2.5	0.52
5	3.5	0.70
6	comb	
7	7.5	1.53
8	5.0	1.05

Users of the cross disperser might find convenient the FOS dekker.