2dF–HERMES Manual

Volume I: User Guide

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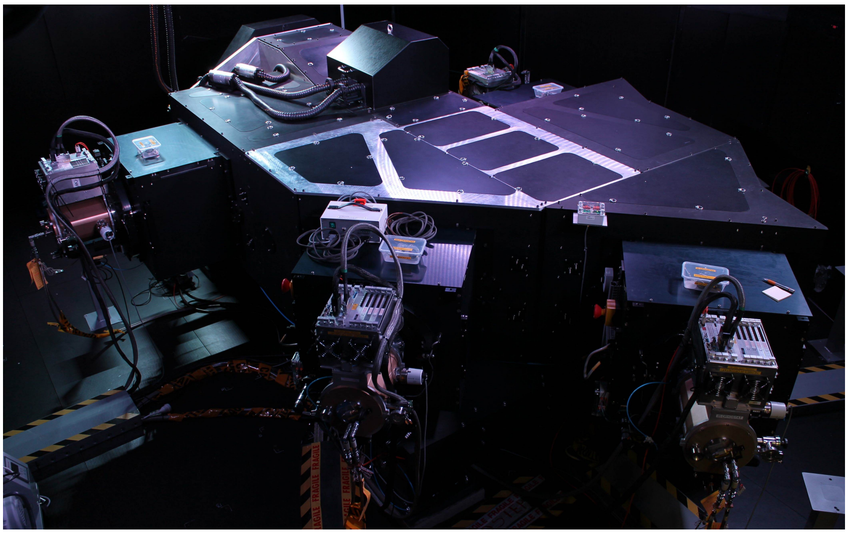


Please read How to use this manual on the inside of the cover.

Parts of this manual:

Siding Spring Observatory
aat.anu.edu.au

Compiled: Thu 9th Feb, 2023

How to use this manual

This AAO Instrument Manual is designed to be a complete reference for the typical user. It is divided into parts, with each part relevant for a particular phase of a program:

Part I Material relevant for preparing a proposal. An overview of the instrument, its capabilities and its overheads is provided.

Part II Material relevant for preparing for awarded time, including details on creating an observing plan, what information or observation description files must be prepared in advance, and other practicalities.

Part III How to operate the instrument and other tasks required at the telescope. Users should be familiar with this part in advance, but certainly need not memorise the whole thing.

Part IV Overview of reducing data.

Part V Supplementary information relevant only to a few observers. This section is often offered as a separate download on the website.

The division of the manual means it is not necessary to read and understand more than one part at any one time.

The manual has been designed with print and on-screen readers in mind, and has hyperlinks throughout to aid in quickly navigating the document.

The AAO welcomes and appreciates feedback on this document. Errors, mistakes, omissions, etc, cannot be corrected if we are not aware of them. Talk to your support astronomer. Printed copies of these manuals are kept in the observing control rooms, and users are invited to mark changes or problems directly on those copies.

Part I

Overview of 2dF and HERMES

Chapter 1

HERMES Overview

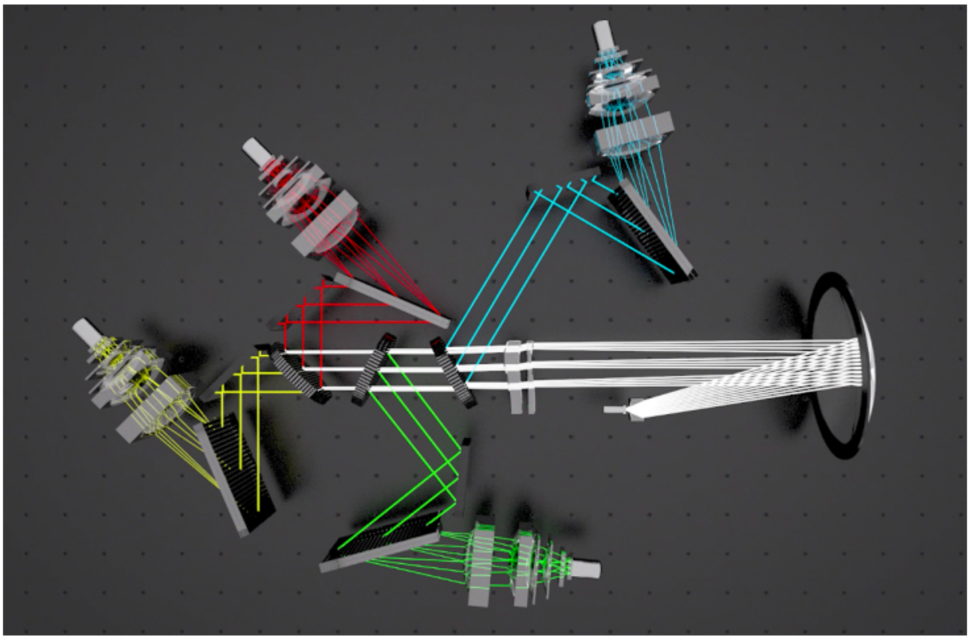


Figure 1.1: *The optical light path of the HERMES spectrograph.*

The High Efficiency and Resolution Multi-Element Spectrograph (HERMES) is a four channel spectrograph, housed in a clean, temperature controlled room located inside the AAT west coudé laboratory. HERMES provides a nominal spectral resolution of R ∼ 28,000 and an option of higher resolution with a slit-mask at R ∼ 45,000, at the cost of approximately 50% light loss. With the AAT+2dF system, HERMES provides high resolution multi-object capability for up to 392 objects.

In its current fixed grating setup, HERMES provides simultaneous observations in the following wavelength regions:

BLUE: 471.5 - 490.0nm
GREEN: 564.9 - 587.3nm
RED: 647.8 - 673.7nm
IR: 758.5 - 788.7 nm

1.1 HERMES Components

1.1.1 Slit Assembly

The HERMES receives light from the 2dF positioning system. The spectrograph slit assembly holds two interchangeable slit units. It provides accurate and stable interfaces for the two fiber feeds coming from 2dF, each containing 400 fibres regrouped in 40 slitlets. Each of the 2 x 40 V-grooved channels in the slit bodies houses a lens relay that changes the F/3.16 focal ratio output of the fibres to feed the collimator at F/6.32. To optimize image quality, the slit is curved (convex and spherical) with a radius of curvature of 935.9 mm.

For high spectral resolution, a slit mask can be inserted manually on a kinematical mount. Installation of the slit mask is a day time operations task, and the slit mask cannot be exchanged during night time observations. The slit assembly also holds a back illumination system, used to position precisely the fibres on the sky target positions.

1.1.2 Collimator and Beam splitters

Post slit, a F/6.3, 9.3 degree off-axis collimator with two spherical corrector lenses produces a 195 mm diameter parallel beam.

Three large dichroic beam splitters separate the beam into the four HERMES channels. The beam splitters that define the wavelengths for the four channels are as follows: 370-492nm (BLUE); 560-593nm (GREEN); 643-679nm (RED); 754-1000nm (IR).

1.1.3 Gratings

HERMES uses four Volume Phase Holographic (VPH) gratings, one in each channel. Two of the four gratings require a mosaic of two gratings on one substrate due to the aperture and line frequency required. The HERMES "BLUE" and "GREEN" channels use single exposure gratings, while the HERMES "RED" and "IR" channels use mosaic gratings. The central wavelengths of the gratings are Blue: 483.3nm, Green: 578.8nm, Red: 664.2nm, IR: 777.8nm. The actual angle of incidence within the assembled spectrograph is within ± 0.1 degrees of the nominal value of 67.2 degrees.

1.1.4 Cameras and Detectors

Each HERMES channel has four F/1.7 cameras, respectively optimized in the Blue (370-550 nm), Green (500-650 nm), Red & IR (600-1000 nm). Four independent shutter systems allows the four channels to have individual exposure times. Each camera feeds one 4096 (spectral direction) x 4112 (spatial direction), 15 μm pixel, Charge Coupled Device (CCD) from the E2V CCD231-84 family. The "BLUE" and "GREEN" detectors are both 16 micron, standard silicon devices with broadband and mid band coatings. The "RED" detector is a 40 micron, deep depletion device with fringe suppression and an ER1 coating. The "IR" detector is a 100 micron bulk silicon device with fringe suppression and a "Multi-9" coating.

The detectors are housed in cryostats operating at about 170 K. Each detector is controlled with an AAO2 CCD controller. These controllers are configured for operation with the E2V CCD detectors to permit readout from one, two or four detector outputs, at various readout rates with windowing and binning options.

1.2 Resolution and Efficiency

Spectral resolution across the detector ranges from 25,000-30,000 for the 4 pixel sampling of the 2 arcsecond slit width (the averaged projection over a circular fibre reduces the projected

5 pixel sampling to an effective 4 pixels). Spectral coverage is $\approx \lambda_c/25$ around the 4 central wavelengths λ_c set by the VPH gratings. A slit mask can be inserted to get the same wavelength coverage with a higher 2-pixel spectral resolution from 40,000-55,000 at the cost of 50% light loss.

The beam splitters, gratings and cameras coatings are optimized for their respective spectral ranges. The HERMES system provides approximately 10% total efficiency from the telescope to the detector signal, such that a 1 hour integration time results in a signal to noise ratio of 100 per resolution element for a 14th mag star.

The currently available beam splitters and gratings have been optimized for the Galactic Archaeology Survey case. Alternatives might be purchased later in order to cover other science domains.

1.3 Spectrograph Focus

The HERMES spectrograph is focused by moving the CCDs. Each CCD is mounted on a moveable stage within the dewar which provides three degrees of freedom: overall piston, a tilt along the spatial axis, and a tilt along the spectral axis. Only the piston and spectral tilt focus mechanisms are motorized. The spatial tilt is fixed at the nominal best position such that all fibres fall within the boundary of the detector. The spatial tilt should only be moved manually by technical staff.

The spectrograph is typically focused each afternoon. The best focus values can differ between the two HERMES slits, hence the focus should be set independently on both slits. Once the best focus values are set, it usually changes minimally day to day.

Note HERMES is sensitive to temperature changes in the spectrograph room, such that if there have been heavy daytime activities in the room or the room door was accidentally left open, the spectrograph focus should be checked prior to starting the science observations. Good focus minimises cross talk between spectra on the detector, and ensures the fibre tramlines can be accurately identified in the data reduction process.

1.4 References

- "The GALAH Survey: Relative throughputs of the optical fibres of the 2dF fibre positioner and the HERMES spectrograph" : Simpson et al. 2016, MNRAS, 459, 1069
- "First light results from the Hermes spectrograph" : Sheinis et al. 2016 SPIE 9908 15
- "Integrating the HERMES spectrograph for the AAT" : Heijmans et al. 2012 SPIE 8446 17
- "HERMES: revisions in the design for a high-resolution multi-element spectrograph for the AAT" : Barden et al. 2010 SPIE 7735 19

Chapter 2

2dF Overview

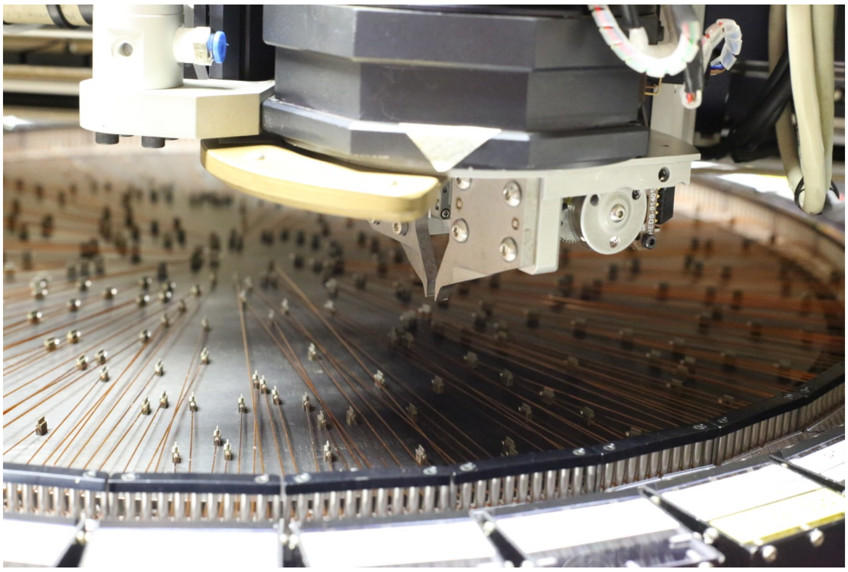


Figure 2.1: *The 2dF Fibre Positioner.*

The 2-degree Field (2dF) fibre positioner is a multi-object fibre-feed to the AAOmega and HERMES spectrographs. It is designed to allow the acquisition of up to 392 simultaneous spectra of objects anywhere within a two degree field on the sky. It consists of a wide-field corrector, an atmospheric dispersion corrector (ADC) and a robot gantry which positions optical fibres to 0.3 arcsecond accuracy on the sky. A tumbling mechanism with two field plates allows the next field to be configured while the current field is being observed.

2.1 Basics

2.1.1 Reconfiguration time and minimum exposure times

For a full field reconfiguration (i.e. to remove the old configuration and replace it with a new one) the reconfiguration time is typically 40 minutes. Therefore, it is not practical to observe a science field for less than about 25 minutes. The only exception is in special cases where only some of the fibres are allocated (with the remainder parked). However, the overheads start to dominate the total time, so generally science fields should be observed for 30 minutes or more.

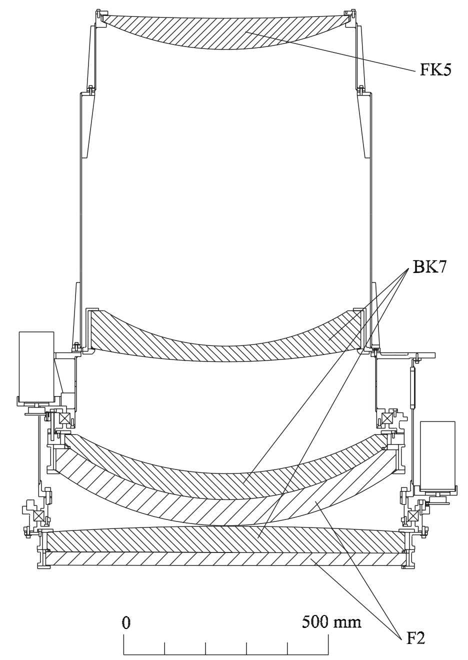


Figure 2.2: Schematic diagram of the 2dF prime-focus corrector in cross- section. The lower two lens elements are the prismatic doublets making up the ADC; these are the first and second elements of the corrector in the light path.

2.1.2 Minimum target spacing

How close targets on a single configured field can be depends on the geometry of the fibre placement. The rectangular shape of the magnetic buttons, and the space taken up by the fibre tail limit the placement of nearby fibres. The absolute minimum is 30 arcsec (2mm), but typically it is 30-40 arcsec depending on location in the field and target distribution.

Note that there is no limit on the spacing of targets in input target definition (FLD) files.

2.2 Atmospheric Dispersion Effects

The large field of view of the 2dF system makes it very sensitive to atmospheric effects. Both variable dispersion across the field, and changes in apparent position as a field rises or sets have a major effect on the light reaching the configured 2dF field plate. Variable dispersion is corrected to some extent by the atmospheric dispersion corrector (ADC), while changes in apparent position can be corrected by reconfiguring a field regularly to keep the fibres accurately placed on the science targets. However, there are limits to the system, some of which can affect your data. The rest of this section describes some of these effects and their mitigation. Your support astronomer can say more about how your particular science may be affected by these issues.

2.2.1 Prime Focus and Atmospheric Dispersion Corrector

The 2dF ADC gives good (but not perfect) correction for the effects of atmospheric chromatic dispersion for fields away from the zenith, up to ZD~60 degrees.

The 2dF corrector is a 4-element optical system. Two of the elements are slightly wedge-shaped optical doublets which can be counter-rotated to correct the atmospheric dispersion (but NOT the effect of atmospheric distortion across the 2dF field). They are designed to give zero deviation but in practice the centering of the 2dF field does vary slightly (at the arcsec level) as they rotate, so it is important to wait for the ADC to start tracking before acquiring a field. For some astrometric or focus test observations it may be best to stop the ADC tracking.

2.2.2 Chromatic Variation of Distortion

This is described in detail in Chapter 16: 2dF Chromatic Variation of Distortion and summarised here for completeness.

Chromatic Variation in Distortion (CVD) is a limitation of the design of the 2dF corrector, which was a cutting-edge design for its time. The practical impact of CVD is an effect similar to atmospheric dispersion, but independent of the atmosphere or Zenith Distance. Like atmospheric dispersion, CVD is a differential refraction effect (with respect to wavelength), but it varies strongly across the field (in a radial direction and with a radial magnitude dependence) and cannot be corrected. For the 2 arcsecond 2dF fibres the best fibre placement is usually to place the fibre for a central wavelength tuned to the relevant program and accept (small) losses at each end of the wavelength range.

2.2.3 Stale Fields: Differential plate scale and ZD

The `configure` software and the 2dF positioner know about these effects and so fibres can be correctly configured for a particular Hour Angle (HA), but as one moves away from this HA the fibre placements become increasingly incorrect. In practice, the observing software positions each fibre at the time averaged position of the target for the period over which the field is intended to be valid.

Most users find full 2-degree fields remain usable for up to two hours when observed close to the meridian. More northerly and fields observed at higher zenith distance are affected to a greater degree, but smaller fields of view are affected to a lesser degree.

2.3 References

- “Multi-object spectroscopy field configuration by simulated annealing”: Miszalski et al. 2006 MNRAS 371 1537
- “Optimal Tiling of Dense Surveys with a Multi-Object Spectrograph” : Robotham et al. 2010 PASA 27 76, arXiv:0910.5121
- “Long-term stability of fibre-optic transmission for multi-object spectroscopy” Sharp, R.; Brough, S.; Cannon, R. D. 2013, MNRAS, 428, 447

Part II

Preparing for observing

This part is a section of the larger 2dF–HERMES manual, which is available from the website.
http://www.aao.gov.au/science/instruments/current/hermes

Chapter 3

In advance of your observing run

1. Contact your support astronomer (see the AAT Schedule). Make sure you discuss with them:
   - What your program is and your observing strategy, including exposure times;
   - Recent performance of the instrument (e.g., how fast will field reconfiguration times be for 2dF);
   - Any questions you have about observation description files, which must be prepared in advance (e.g., `.FLD` files for 2dF, finder charts for KOALA, observing scripts, etc.);
   - Which particular mode/setup you plan to use for your program.
   - When you will be arriving at the telescope or remote observing site.
2. Fill out your Travel Form, *regardless of whether you will be observing remotely or at the AAT*. This allows the AAO to make appropriate reservations, etc.
3. Read this documentation, especially Parts II: Preparing for observing and III: Observing with 2dF+HERMES. Users of 2dF *must* be prepared to use `configure` at the telescope.
4. You should plan to arrive early, preferably the day before your first night on the telescope, especially if this will be your first observing run with this particular instrument/telescope. This will give you time to discuss your program with your support astronomer in detail, familiarise yourself with the data reduction software, and the computing and observing system at the telescope or remote observing site.
5. If observing with 2dF, prepare your `.FLD` configuration files. If observing with another instrument, prepare finding charts for your targets. Preparing `.FLD` files is a complex task, and should not be left until the last minute.

Astronomers are *strongly* encouraged to reduce their data in real time at the telescope. Although such "quick-look" reductions often require revisiting afterwards, they are crucial to ensuring the best quality data is obtained. AAOmega and HERMES data are reduced using the `2dfdr` software environment. Reduction facilities are available at the AAT and via the remote observing system, but users may wish to download and run the software e.g., on their laptop. The 2dfdr webpage provides all necessary links and information for the data reduction task.

Chapter 4

Planning your observing

To maximise the efficiency of your observations, you should plan what data you will need, and what order it will be taken in. This chapter will help you determine what data are needed.

4.1 Typical Observing Sequence

1. **BIAS** – BIAS frames are important to characterize CCD noise.
2. **DARKS** – DARK frames are important for faint targets. For bright targets these may not be needed. Discuss whether these are required with your support astronomer.
3. **FIBRE FLAT** — For tracing individual fibre spectra across the CCD, and some flatfielding.
4. **ARC** — For wavelength calibration.
5. **OBJECT frames** – These should be split up into at least 3 separate exposures so that cosmic rays can be removed by the reduction software.
6. **OFFSET SKIES.** These are used for fibre throughput and normalisation of sky fibres. Discuss whether these are required with your support astronomer.

4.2 Calibrations and Overheads

In this section we discuss the overheads incurred and the minimum calibration requirements for HERMES data.

4.2.1 Detector Settings

HERMES CCDs can be readout using SLOW, NORMAL and FAST readout modes with 1, 2 or 4 amplifiers. Tables 4.1 show the gain, readout noise, and readout times for the various readout modes using a single top left amplifier. The values for other individual amplifiers are very similar to those in Table 4.1. A faster NON-ASTRO readout mode is also possible but is currently not supported by the current instrument software. This mode is only available for engineering tests using custom control software. If this NON-ASTRO mode is required, please contact your support astronomer.

Using the two Left (top and bottom) amplifiers or two Right amplifiers, reads the detector in the spatial direction. Fibres 1 - 200 are readout with the bottom amplifier and fibres 201 - 400 are readout with the top amplifier. This avoids splitting the data in the spectral direction and

Table 4.1: HERMES Readout Modes

CCD	Mode	Readout time (sec)	Gain (e^-/ADU)	Read Noise (e^-)
BLUE	Fast	144	2.6	4.1
	Normal	282	1.8	3.2
	Slow	420	1.2	2.9
GREEN	Fast	144	3.0	4.4
	Normal	282	2.0	3.1
	Slow	420	1.4	2.6
RED	Fast	144	3.1	4.9
	Normal	282	1.9	3.1
	Slow	420	1.4	2.9
IR	Fast	144	2.7	4.4
	Normal	282	1.5	3.5
	Slow	420	0.7	3.0

is the default amplifier setting.

The default readout mode is set to FAST.

Using two Top amplifiers or two Bottom amplifiers reads the detector in the spectral direction, such that the first half of all fibres are readout with the Left amplifier and the second half of all fibres are readout with the Right amplifier. This splits the spectrum of each fibre. Using all four amplifier reads the detector in 4 quadrants.

Using any two amplifiers halves the readout time given in Table 4.1.

Each CCD can be binned independently in spatial (Y) and up to 2x in the spectral (X) direction for all readout modes. The readout times for binned data using two Left amplifiers with FAST readout are as follows:

X=1, Y=1, 71sec
X=2, Y=1, 52sec
X=1, Y=2, 36sec
X=2, Y=2, 26sec

All readout modes in all CCDs reach saturation at 65536 adu. The level of dark current in the four CCDs is between 1.5-3.0e/pixel/hour.

4.2.2 Calibrations

At minimum each configuration observed with HERMES requires a fibre flat and arc exposure. More frequent arcs (eg. before and after a science frame) can be taken for higher precision wavelength calibration requirements. Fibre flats need to be taken only once for a given configuration, provided the slit unit has not been moved.

For fibre flats, there is a selection of quartz lamps installed on the 2dF top end ring. The 75W lamps are recommended for HERMES flat exposures. The typical exposure times for fibre flats are given in Table 4.2 using 2x 75W Quartz lamps installed on the 2dF top end ring.

Table 4.2: HERMES Calibration exposure times

CCD	Mode	Arc Exposure (sec)	Flat Exposure (sec)
BLUE	Nominal	180	180
GREEN	Nominal	180	160
RED	Nominal	180	90
IR	Nominal	180	90

For different lamp sources the user should experiment with the exposure time to verify there is sufficient flux for their science goals.

HERMES wavelength calibration uses 4 ThXe lamps that are currently installed on the 2dF calibration flaps, directly illuminating the corrector lens. All ThXe lamps are selected by default in order to get sufficient flux level in a timely manner. The typical exposure times for arc exposures are given in Table 4.2 using these 4 ThXe lamps.

The values in Table 4.2 are approximate and only given for guidance. These exposure times have provided sufficient flux for wavelength accuracy within 0.1 pixels and flat field counts to achieve a signal-to-noise of 100 per resolution element. For different science requirements the exposure times should be adjusted.

Chapter 5

Preparing field description files (FLDs) for Configure

The `configure` program takes as input a text file that describes all possible targets to be observed. The file is usually referred to as an "FLD" file after the regular `.fld` extension in the filename. General guidelines and suggestions for FLDs are discussed first, followed by instructions for including guide stars, and finally a description of the format is given. All of this information is critical to the success of a program, so pay careful attention.

How to run the `configure` program is described in Chapter 6: Using Configure.

5.1 General Guidelines for FLD Files

Science targets No more than 800 targets and these should cover a relatively small range in target magnitude (less than 3 mags is the standard constraint, but talk to your support astronomer if you require more detail here).

Calibration sources If required, these should be set to Priority 9 in the `.fld` file with the priority of all science targets shuffled to lower levels so that calibrators are always allocated.

Sky fibre positions You will need 20-30 sky fibres in the observation, so 50-100 possible sky positions should be enough. Eyeball the sky fibre positions to check they are actually blank regions.

Standard star calibrators We have had some success recently in including a small number (1-2 objects per configuration) of standard star calibrators in 2dF fields. These must be chosen to be faint, to avoid contaminating science spectra. Drawing the calibrators from the recent sample of White Dwarfs and Hot Sub-Dwarfs of Eisenstein et al. ApJS, 2006, 167, 40 from SDSS has worked well. Absolute flux calibration is not possible with a fibre system such as 2dF/AAOmega, due to the unquantifiable aperture losses in any given observation, but including a standard star in each field plate observation can improve the quality of internal spectral calibration, and monitor data quality. All caveats relating to astrometric accuracy apply to calibrator data as well as science and guide data.

Assigning Specific Wavelengths to specific targets The telescope's Positioner GUI also handles atmospheric refraction effects when working out the positions of fibres on the field plate - including the effects caused by different observation wavelengths. Normally a single wavelength is chosen for all fibres and is applied by the support astronomer. However, it is possible that you may prefer to have fibres configured for different wavelengths. It is now possible to specify up to 9 different wavelengths in the `.fld` file (also shown in the example.fld file).

A warning on the use of target priorities Configure is very good at allocating targets based on the 9 possible priority levels (9 is highest priority). However, the user should exercise some restraint when using the available levels. Using all of the available priorities to derive a complex priority selection function will almost always yield very limited returns at the expense of usability. For most programs the number of targets in a given `.fld` file must be restricted (as described above) in order to allow the configuration process to be completed in an appropriate amount of time (20mins). A field that is stacked with a large number of low priority targets will take a long time to configure. If these targets are indeed low priority then the user should consider carefully whether their inclusion is worth the overhead in configuration time they will incur.

5.2 Guide Stars

Guide stars (fiducials) are crucial to the success of your observations so pay careful attention here. Guide stars not only are used to guide the telescope, but also determine the field plate rotation, and set the relative position of the science fibres on the sky. Poor choices may mean that no light falls on science fibres!

- 2dF has eight guide bundles available. All eight should be allocated wherever possible. This will require 20-30 or more candidate guide stars *well distributed* across the field plate to ensure all guide fibres can be allocated and prevent guide star selection compromising science fibre placement.
- Guide stars as bright as 8th magnitude in V can be used, but typically stars in the range 12–13.5 are best. Fields closer to the moon will require brighter stars. Stars fainter than 14th magnitude in V are typically too faint.
- The range in guide star magnitude should be made as small as possible so that all guide bundles are evenly illuminated. In practice, >1 mag is a good range, and 0.5 mag is best.
- Guide stars MUST be on the same astrometric system as your targets. Otherwise, you will likely place your science fibres on blank sky.
- Be aware of proper motions, particularly in brighter guide stars. Including proper motions in your FLD file is highly recommended.

Below are several warnings when choosing guide stars.

- Simply selecting some bright guide stars from SIMBAD or GSC is NOT going to work, your astrometric solution MUST be the same for the guide stars AND the targets, and good to 0.3arcsec or better. This is a requirement for 2dF observations.
- UCAC-2 and 2MASS sources have proved successful in recent years, although the USNO survey seems to be somewhat inconsistent (probably due to plate boundary effects).
- SDSS is an obvious source of guide stars. However, all stars need to be eyeballed as SDSS has artefacts at the magnitudes required here. Marginally saturated stars, which do not suffer obvious defects on examination, have been found to still give excellent results with AAOmega (the SDSS astrometric data for these objects actually comes from smaller edge CCDs so the stars do not actually saturate in their astrometric reference frame).
- **Eyeball your guide stars**. Reject galaxies, reject binaries, reject objects with junk magnitudes. Stars should NOT be used blindly (guide globular clusters are next to useless and stars should not have spiral arms).

- The target and guide star astrometry MUST be on the same system. Simply using two different catalogues that independently claim to be J2000 will result in poor acquisition and low throughput.

An interesting paper on the effects of poor astrometry on Signal-to-Noise is Newman, P.R. 2002 PASP 114 918

5.3 Format

An FLD file is a structured text file with two parts. The first part is a header. The header consists of keywords which determine certain characteristics of the whole field, such as field centre, and also can affect how the rest of the file is interpreted by the software. The second part consists of a white-space separated table of potential targets for observing. Each line can have up to 256 characters, and comments can be indicated using either an asterisk (*) or hash (#) character. Special characters, particularly quotes, should be avoided.

5.3.1 Header

The header consists of a set of keyword – value pairs, one per line. The keyword is first on the line, and separated from its value by a space. Everything after the space to the end of the line is taken to be the value. The keywords are:

LABEL A string giving the target field label (which will be stored in the header). May include spaces.

UTDATE The UT Date of observation. In practice the date is not important because `configure` assumes the field will be observed when overhead (±4 hours). The format is `yyyy mm dd.dd`. The `.dd` portion is optional, and specifies the time as a fractional part of the day.

CENTRE Field Centre R.A. and Dec. The format is `hh mm ss.ss -dd mm ss.s`. The sexagesimal rounding must be correct: `22 60 34.5` is an error, as is `22 45.3` (i.e., no seconds and decimal minutes).

EQUINOX Coordinate equinox for the rest of the file, default is J2000. (Note that this is equinox and not epoch).

ARGUS *not used for 2dF*

WLEN*n* Defines specific wavelengths for individual target positioning optimisation[1]. Can be repeated up to nine times, where *n* is from 1 to 9. The wavelength must be specified in angstroms and in the range 3000Åto 10000Å (optional).

PROPER_MOTIONS Determines if the input file includes proper motions (optional, does not take a value.) If this header is included, all coordinates must be in epoch 2000.

5.3.2 Columns

Any non-comment line that does not start with one of these keywords will be assumed to signal the start of the target list. Columns of the target list are separated by one or more spaces. Each line ends with a comment column, which can include spaces. The equinox of all coordinates given in the file must be that specified in the EQUINOX line.

The columns are:

[1] WLEN does *not* determine the central wavelengths of the spectrograph

Name The name of the object *without contain spaces*, but underscores are acceptable.

Right ascension in the format `hh mm ss.ss`. The sexagesimal rounding must be correct: `22 60 34.5` is an error, as is `22 45.3` (i.e., no seconds and decimal minutes).

Declination in the format `-dd mm ss.s`. As above, the sexagesimal rounding must be correct.

Position type A character indicating the type of object: `P` — program/science target, `S` — blank sky, `F` — guide star. If a `WLEN`*n* item has been defined in the header, that wavelength is assigned to a target using `P_w`*n* in place of the `P`, and with the *n* corresponding.[2]

Target Priority (1-9) with 9 being the highest priority. If you are not using priorities you should set all priorities to the same value, say 1. Guide stars and sky regions should be set to 9.

Magnitude The magnitude of the object in format `mm.mm`. This is used for diagnostic plots within the data reduction software, and is not critical to observing.

Program Id This is an integer uniquely identifying a specific project. This is ignored, but must not be omitted.

Proper motion in RA If the `PROPER_MOTIONS` keyword is listed in the header, then this column contains the east-west proper motion in arcseconds in RA[3] per year. A proper-motion correction is made at the time of configuring (immediately before observing) for the position of the object. If the `PROPER_MOTIONS` is not set, then this column should be ommitted.

Proper motion in DEC Same as above, but for declination/north-south direction.

Comment Any remaining text up to the end of the line is taken as a comment, and will be included in the output FITS fibre table. Some additional instructions can be included using special keywords in the comment field, and are described in the `configure` manual available from your support astronomer.

5.3.3 Example FLD file

```
* A comment about this file
# Another comment!
LABEL My favourite field
UTDATE 2013 1 1
CENTRE 21 00 00 -20 00 00
EQUINOX J2000
PROPER_MOTIONS
WLEN1 4500
WLEN2 8600

# Proper motions in arcsec/year in coordinates

#             R. Ascention   Declination               Prog Proper Motion    Comments
# Name         hh mm ss.sss   dd mm ss.sss         mag  ID   ra     dec
347-187448   +20 59 20.893  -20 39 41.425  P     9  13.8  0    -0.0073 -0.0150  A nice star
354-188889   +21 02 41.304  -19 15 45.385  P     9  13.0  0     0.0344 -0.0339  A nicer star
349-186707   +20 56 30.735  -20 14 04.764  P_w1  9  11.6  0     0.0017 -0.0004  feat. at 4500A
353-190083   +21 02 15.107  -19 30 55.424  P_w2  9  13.6  0    -0.0261 -0.0252  Calcium Triplet
351-189626   +20 58 04.132  -19 49 03.594  P1    9  12.2  0     0.0124 -0.0262  Random galaxy
```

[2] If no wavelength is assigned here, the default wavelength, which is set at the time of observation, is used. All fibres with specific wavelengths will be positioned optimally for that wavelength and the observed .fits files have a "WLEN" field in the fibre information table that indicates the actual wavelength the object was configured for.

[3] Many catalogues give the proper motion as arcseconds on the sky. The difference between arcseconds on the sky and arcseconds in RA coordinate is the cosine of the declination.

Chapter 6

Using Configure

The `configure` software is used to allocate fibres to targets while respecting the physical constraints of the hardware. The same version is used for AAOmega, HERMES and 2dF. The current version of Configure implements a Simulated Annealing (SA) algorithm. The advantages of SA are explored thoroughly in Miszalski, Shortridge and Saunders et al. (MNRAS, 2006, 371, 1537), and are summarized in an article in the February 2006 AAO Newsletter.

For users who do not wish to use Simulated Annealing, a version of `configure` which uses the original "Oxford" algorithm is also packaged with `Configure7.3` and later packages.

6.1 Installing Configure

The latest version of `configure` can be downloaded from the AAT's operation site:

http://aat-ops.anu.edu.au/2df/configure/

All you have to do is expand the appropriate gzipped (.tar.gz) file into a convenient directory on your system:

```
tar -zxvf configure-8.1.Linux-Intel64bit.tar.gz
```

6.2 Running Configure

6.2.1 Updating the 2dF Distortion Model

NOTE: This is only required when running `configure` away from the AAT. The software at the AAT automatically uses the latest files.

To correctly allocate fibres to science targets, `configure` must have an up-to-date model for the 2dF astrometry, and knowledge of which fibres are functioning. Both of these change regularly (whenever the poscheck is redone or a fibre is broken/repaired). These files are therefore not included with the distribution of `configure` and should be updated regularly. The necessary files can be fetched from the AAT operation site:

http://aat-ops.anu.edu.au/2df/latest_config_files

The files required are listed in Table 6.1.

Place these files in the same directory as the `configure` executable before starting the software.[1]

NOTE:

Even if you do use the most current fibre and astrometric information, **you will still have to**

[1] In addition to the directory containing `configure`, the software also looks in the directory given by the `CONFIG_FILES` environment variable.

Table 6.1: *2dF Distortion Model Files.*

`tdFlinear0.sds`	Plate 0 Linear Coefficients
`tdFdistortion0.sds`	Plate 0 Distortion Information
`tdFlinear1.sds`	Plate 1 Linear Coefficients
`tdFdistortion1.sds`	Plate 1 Distortion Information
`tdFconstantsDF.sds`	Fibre status information.

tweak your fields at the telescope, since things can and do change on very short notice. This is especially true at the start of your run.

6.2.2 Starting the Software

NOTE: Do not run `configure` *on AATLXY (the computer running the 2dF software). If you want to run configure on an AAT computer, first ssh into AATLXH and log in using your visitor credentials.*

Starting `configure` just requires running the appropriate executable, either from the terminal, or, if on Mac OS, by double clicking the executable in the Finder window. Remember that unless you have added it to your path, you will need to provide the full path to the executable.

```
laptop> cd configure-7.18-Linux
laptop> ./configure
```

Once launched, Configure asks you to select the instrument you wish to configure for (Figure 6.1; 2dF-HERMES, 2dF-AAOmega, 2dF, 2dF-old-404, FLAMES, 6dF).

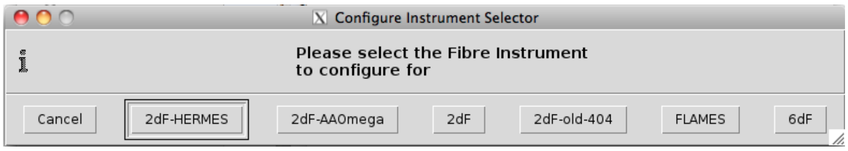


Figure 6.1: *Configure instrument selection window.*

Once the instrument has been selected the full `configure` interface will come up, including the main window, basic sequence window, and allocation display. To get started, follow the steps in the "Basic Sequence" window (Figure 6.2):

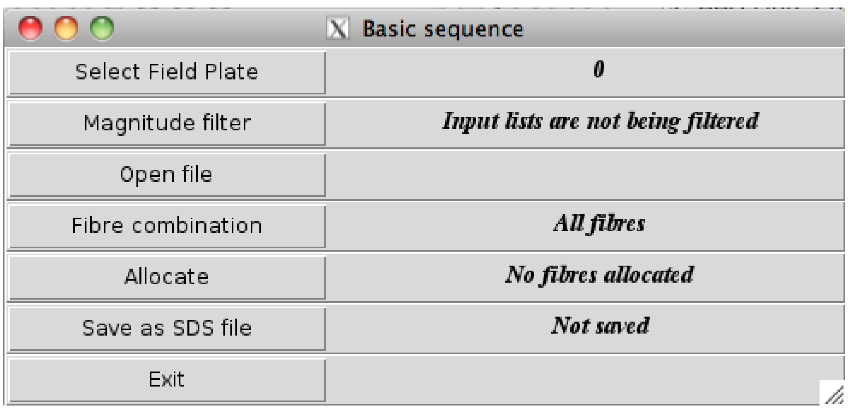


Figure 6.2: *Configure basic sequence window.*

- Select the field plate to prepare the configuration for (plate 0, plate 1 or plate 2 which can be observed with either plate 0 or plate 1).
- Apply a magnitude filter (this is very rarely used).
- Open the `.fld` file to be configured.
- Select the fibre combination to be configured (this is rarely changed from the default "All Fibres").

Once these options are set and the `.fld` file opened, the "Allocate" button can be selected. This opens the "Allocation" window (illustrated in Figure 3) from which configuring parameters can be set. The default settings are fine for the majority of programs but more detail on the available parameters, including hidden Expert options, is given below.

"OK" initiates the configuration which can be followed in the main Configure window.

When configuration is complete the simulated 2dF window will illustrate the configured fibre positions.

At this stage it is a good idea to check the numbers and distributions of guide stars configured and also that the configuration is observable over a range of hour angles. This can be checked using Commands menu item "Check over Hour Angle" and checking over 4 hours. Those fibres that are flagged as having conflicts over this time should be reallocated or deallocated by clicking the relevant fibre in the simulated 2dF window and using the Commands menu to deallocate and/or reallocate the fibre.

Once the configuration is complete the binary file for input into the telescope should be saved, using "save as SDS file" from either the "Basic Sequence" window or the File menu. You are now ready to observe these targets.

6.2.3 Allocation Options

There are a number of options available within the Configure algorithm, selectable from the "Allocation" window, illustrated in Figure 6.3.

Annealing This governs how quickly the annealing routine cools during the allocation process. The Standard setting is generally fine.

Weight close pairs: ThetaMin; ThetaMax In some circumstances one may wish to give additional weight to closely packed targets, at the expense of overall target yield. These allow this to be setup, but beware of the odd effects it will have on your allocation. This option has not been extensively tested to date.

Cross beam switching If the observation requires Cross Beam Switching (CBS) between pairs of fibres, then the user should first generate the paired target positions using the menu option Commands->Generate CBS pairs and then set the CrossBeamSwitching flag. This gives additional weight to targets which are successfully allocated pairs of fibres, at the expense of overall target yield.

Straighten fibres This gives increased weight to allocations which have fewer fibre crossovers. While this will have some impact of target yield, the effect is small/undetectable for most source distributions and results in fields that typically require fewer fibre parks between configurations, hence reconfiguration is faster (by 10–20 minutes in some cases). Figure 13 of Miszalski, et al. (MNRAS, 2006, 371, 1537)[2] shows the effects of this straightening. It can have adverse effects on target priorities and so the concerned user will need to experiment with this option to determine the optimal solution.

[2] arXiv:astro-ph/0607125

Collision Matrix It is occasionally useful to save the matrix of fibre collisions which has been calculated for this field. This enables quick restarts of the software later on. This file can however be rather large.

Enforce sky quota This option forces the allocation of the requested number of sky fibres. This can result in subtly lower target yields for some fields, although the effect is small/ undetectable for most source distributions (accepting that the full sky quota is allocated to skies). Most datasets will be of little value with less than 15 sky fibres. 20-30 fibres is more typical for most projects.

Peripheral weighting for Fiducials This gives enhanced weight to selection of stars towards the edge of the field, which is typically beneficial for acquisition, and prevents all of the fiducial stars being crowded into a small area of the plate, as can happen with the SAconfigure algorithm.

Weight fiducial target pairs For CBS observations one may wish to allocate the fiducial fibres in pairs in order to guide in both positions of the beam switch. Setting this flag gives extra weight to paired fiducial allocation. Note: it is often more efficient in terms of fibre allocation for the user to allocate fiducials by hand but to ensure that half of the fibres (e.g.50, 150, 250 and 350) go to position A guide stars, while the other half (e.g.100, 200, 300 and 400) go to position B guide stars. There is no requirement that these stars be the same set in the A and B positions.

Number of background threads to use The calculation of the fibre collision matrix is very CPU intensive. On a modern multi CPU machine Configure can hijack all of the available CPUs and run a number of background threads, this vastly reduces the allocation time. For a single CPU machine, there is nothing to gain here.

On-the-fly collision calculation By default, the the collision matrix is calculated in full in advance of the annealing (this is the way Configure-v7.4 operated when SAconfigure was first introduced). An alternative is to calculate it on-the-fly. This ensures that A configuration is achieved as quickly as possible. This configuration will be HIGHLY sub-optimal. The longer the process is allowed to run, the greater the region of parameter space that is investigate and the the better configuration will be. In the limit of the annealing process, the two approaches will produce identically good configurations, and will take identically long to reach this point. There is therefore often little point in doing the calculations on-the-fly. In fact this option may allow inexperienced/inpatient users to produce sub-optimal configurations. It can however, be used in cases where a pretty good configuration is needed rapidly.

Note: the original Oxford configuration algorithm, which can be used instead of the annealing by running the configureTrad command, will be far quicker.

Number of Sky fibres The indicated number of sky fibres will be assigned (but see the note above on enforcing the sky fibre quota).

6.2.4 Additional Expert allocation options

These options can only be accessed via the Expert user mode which one activates via the toggle setting in the Options menu. These settings are generally for support astronomers and expert users.

Fibre clearance, Button clearance and pivot angle These options are mainly for the 2dF support staff. If you do not know what they are used for then you should not adjust them.

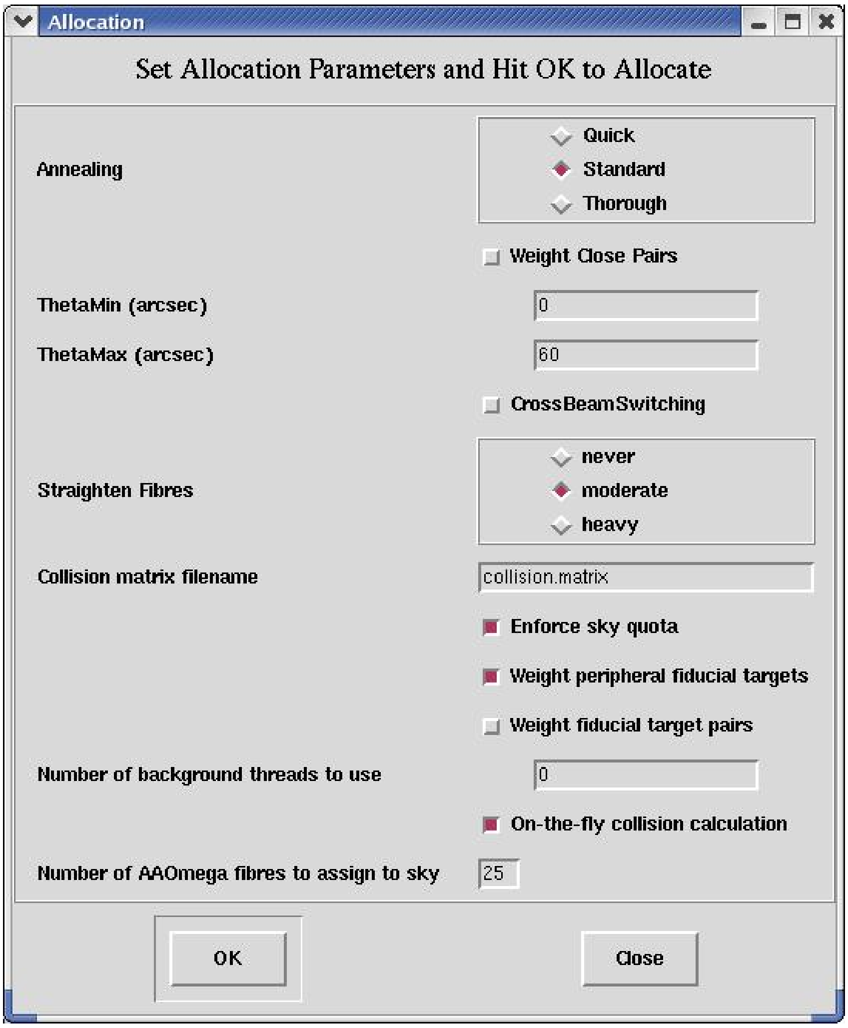


Figure 6.3: *Allocation options in Configure.*

Note that the 2dF robot has safe values HARD WIRED into the system and so a configuration which is outside these bounds will be flagged as INVALID at configuration time. These settings should only be used to restrict the values to tighter constraints for reasons that are beyond the scope of this web page.

Random Seed and Percentage of allocations sampled If one needs to configure more quickly, e.g., if the field is pathologically complex (usually centrally condensed or with heavily clustered targets) and the complexity cannot be reduced by reducing the number of targets in the input FLD file, then it is possible to sparse sample the collision matrix and speed up the process. If you need to use this option, it should be discussed with your support astronomer. The principle is, for such configurations, that the slow speed is caused by the large number of rather similar configuration that are available (in essence many objects could be configured with many different fibres without changing the basic properties of the configuration). The sparse sampling reduces the number of available allocations for these heavily oversampled objects, but does not remove the object from the possible allocations. Note that at this time the effect of this sparse sampling on properties such as spatial clustering is unknown. In most cases a better construction of the .fld file, with serious thought given the the true requirements of the project, is more appropriate than using sparse sampling on a poorly defined input file. To use the sparse sampling, set the seed for the random number generator, and then set the percentage of allocations to sample. Using only 10% will result in a very quick configuration, but most likely a poor yield. Using 80% seems to give a significant improvement in speed, without an obvious detrimental effects on the yield. Note: this mode is still underdevelopment, and it's effects are poorly understood at this time.

6.3 Wavelength Optimising Fibre Placement

In order to achieve a wide field of view and good image quality over that entire field of view the 2dF prime focus corrector suffers from Chromatics Variation in Distortion (CVD; Section 2.2). This means that while the Atmospheric Distortion Corrector (ADC) accounts for the effect of the atmosphere on your target object's white light apparent positions, the prime focus corrector moves your target on the field plate as a function of wavelength. The effects can be quite large, up to 2 arcsec in the worst case when considered over the full wavelength range accessible to 2dF and over the full 2 degree field. 2dF knows about CVD and so you must specify for what wavelength you want 2dF to put the fibres in the correct position. This must be the compromise which best suits your program goals (e.g. 400nm for Ca H+K and the Balmer lines, 860nm for Ca Triplet work, 600nm for low-resolution broad-band redshift measurements with the 570nm dichroic or 670nm for low-resolution broad-band redshift measurements with the 670nm dichroic).

Part III

Observing with 2dF+HERMES

This part is a section of the larger 2dF–HERMES manual, which is available from the website.
http://www.aao.gov.au/science/instruments/current/hermes

Chapter 7

Outline of observing

This chapter is a reference, providing an overview of the necessary tasks for obtaining successful observations.

7.1 During the Afternoon

1. Confirm Instrument Setup and preparation with support astronomer/afternoon tech.
2. Confirm computing setup.
   (a) Make sure you are ready to reduce data with a recent/current version of 2dfdr on either an AAT data reduction machine or your laptop. Note the best version to use is typically that on the AAT computing system.
   (b) Confirm the correct `.idx` file(s) for use with `2dfdr` are available.
   (c) Confirm that you can use `configure` on `aatlxa`.
   (d) If you will be using your personal computer, make sure you know how to access files in the appropriate directories on the AAT computer system.
3. Plan your observations using `ObsPlan` if required, described in § 7.4: Planning 2dF observations with `obsplan`.
4. Prepare all observing files, if the astrometric solution is available.[1]
   (a) All 2dF field description files (`FLDs`) must be allocated to binary `sds` files using `configure` for loading onto the telescope. Because the parameter files change for each observing run, These should be prepared using the version of `configure` on the AAT computer system, or at least with the most recent version of the 2dF parameter files.
   (b) Copy the final `sds` files to the working directory for the night.

7.2 Observations

1. General calibration frames: sets of bias and dark frames are typically taken during the afternoon.

[1] The astrometric solution is typically updated each time 2dF is re-installed on the telescope, sometimes more often. This process is called "poscheck,"

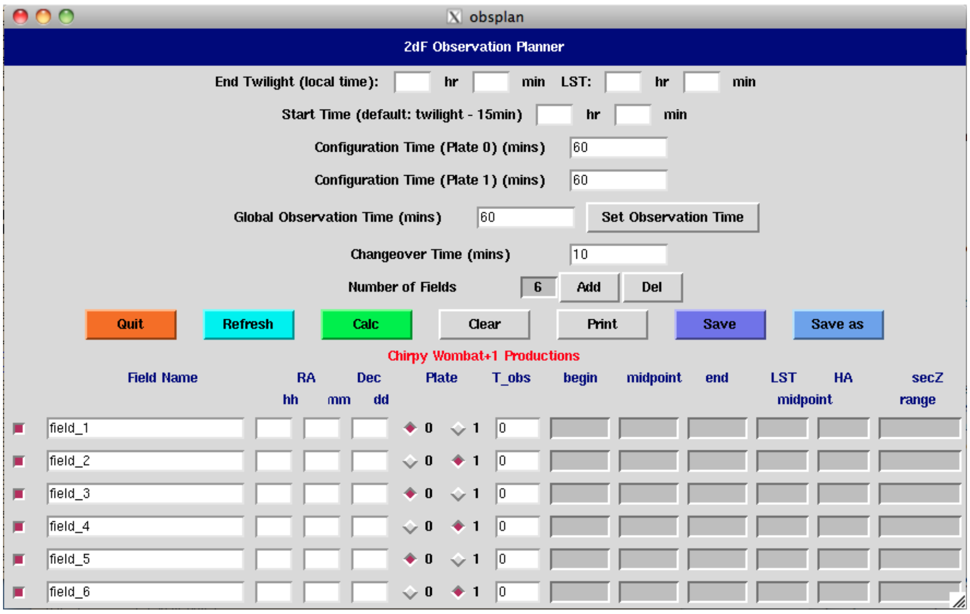


Figure 7.1: *`ObsPlan` observation planning tool.*

2. During the night, your support astronomer will configure your sds files on the specified plate. Once ready, the telescope will slew to the appropriate position, and a flat and an arc frame will be taken. A seeing measurement can be taken between these calibration frames. Once the guide stars are acquired to the night assistant's satisfaction, the science exposures are then started and the robot will start configuring the next sds file on the other plate. After the science observations finish and read out, the telescope then slews to the next position specified by the next sds file.

3. Once each set of science observations are completed it is important to copy the data to your working directory and start the reduction using `2dfdr` to ensure that the data are as required. The location of the data are described in § 7.5: Where are the data?.

7.3 At the end of the run

Ensure you take all of your data with you. Means to do this are described in § 7.6: Taking away data

7.4 Planning 2dF observations with `obsplan`

The `ObsPlan` tool (Figure 7.1 is used for planning a night of 2dF observations. Assuming a starting time for the night (usually 15 minutes before the end of astronomical twilight), and introducing the expected changeover time between plates, `ObsPlan` computes at what time and airmass a field plate (identified by name, RA and Dec) can be observed. This tool also takes into account the time that 2dF needs to configure a plate and that field plates have to be configured alternatively (i.e., you cannot configure two consecutive fields on the same plate, if you do so the configuration time will be added to the planning time). `ObsPlan` is intuitive to use and very helpful, as it provides the starting times for configuring 2dF (see Section 12.2), as well as the middle and final times and airmasses for the observed field.

This application is available on `aatlxa`, and can be started from the terminal by typing `obsplan`. This starts the software, and opens a window in which all parameters (observing plate, coordinates and name) of a field can be introduced. Each observation field is entered in a different row, with the possibility of observing it or not by just clicking the left box. To compute the observing times, just click in the green Apply button and all values will be updated.

7.5 Where are the data?

Data taken with HERMES is available on the AAT control room computer systems at:

```
/data_lxy/aatobs/OptDet_data/YYMMDD/CCD_N
/data_lxy/aatobs/OptDet_dummy/YYMMDD/CCD_N
```

Note that YYMMDD is the UT date (start of night) and N is for CCD number (1 - 4). Regular data files (in OptDet_data are named with a convention like 15apr10023.fits for run 23 of CCD1, or 15apr20023.fits for the corresponding frame of CCD2. Dummy data files have filenames consisting of a single lowercase letter starting at "a", e.g., a.fits, b.fits, etc.

A large scratch disk is available for use the data reduction computers at the AAT. These are per user, and per computer, but each disk is network mounted to the other data reduction computers. These are at e.g., /data_lxa/visitor2, /data_macb/visitor6, etc. Data should *not* be reduced in the home directories.

NOTE:
These disks must be considered volatile. They are not backed up. Inactive accounts are removed after 30 days, and in some cases data may be removed the day after a given run.

7.6 Taking away data

A typical night's data tends to be 2–10 GB, depending on the number of frames, etc. By far, the easiest option is to copy data onto a personal laptop or external USB. The observatory also provides DVDs if needed.

7.6.1 Copy to personal computer

For computers connected to the network within the AAT control room, or in the Remote Observing room in North Ryde, the data can be copied via scp, sftp or rsync directly from the AAT computer system via, e.g.,

```
  scp -r visitor2@aatlxa:/data_lxy/aatobs/OptDet_data/130123/* my-data-dir/
  rsync -rv -avz --exclude="drt_temp*" --modify-window=1 visitor2@aatlxa:/data_lxy/aatobs/OptDet_data/130123/* my-
data-dir/
```

Programs which support scp or sftp are freely available for windows computers as well.

Alternately, data can be copied from the AAT computer system directly to external computers via e.g., scp, sftp, ftp, etc. This is convenient to send the data to your home institution if your institution allows incoming connections.

7.6.2 Copy to USB Drive

An USB portable hard-drive can be mounted on either aatlxa or aatmacb in the AAT control room (both are located on the shelf above the terminals).

The mounted hard-drive should be visible on the desktop area of aatlxa. If not, seek help from the AAT IT staff.

7.6.3 Writing data DVDs

The data reduction machines are equipped with a DVD writers. DVDs and cases (hard or soft) can be found in the consumables cupboard at the far end of the control room. A *limited number* of these can be made available to the visiting astronomer. To write a DVD:

- Copy all of the data into a directory structure on `aatlxa`. A new subdirectory is required for each DVD, and should be smaller that the limiting DVD capacity (4.7Gb).
- at the top of the subdirectory tree, type `dvdwrite`. This bring up the tcl/tk front end to the `dvdwrite` software.
- Use the yellow browse button at the top right to select the subdirectory to write to DVD. Select the Premaster and Burn button and then hit Do it!.
- The DVD should now write, and then do a bit-by-bit validation of the disk against the input data.

Chapter 8

Outline of Instrument Operation

This chapter is simply a reference which provides a quick overview with links to the various detailed descriptions elsewhere in this document.

8.1 During the Afternoon

1. Confirm Instrument Setup and preparation with support astronomer/afternoon technician.

    (a) Check the resolution mode is correct and the slit-mask is installed if needed.

    (b) Check with the technicians that the vacuum gauges are off, and no lights are on in the spectrograph room.

    (a) All 2dF field description files (`FLD`s) must be allocated to binary `sds` files using `configure` for loading onto the telescope. Because the parameter files change for each observing run, These should be prepared using the version of `configure` on the AAT computer system, or at least with the most recent version of the 2dF parameter files.

    (b) Copy the final `sds` files to the working directory for the night.

2. Ask for the instrument/telescope to be released before using the observation interface.

3. Check/update the system for today's UT date[1].

4. Configure the first fields on 2dF. **NOTE,** configuring the fields on nights with PosChecks cannot be done till after the PosCheck. However, the rest of this list can still be completed.

5. After 4 pm, and after checking with the afternoon technician, the dome lights can be put out.

    (a) Check that there are no lights left on in the dome. Note that the visitor gallery lights are on a timer, and switch off automatically a few minutes after the main lights are out.

    (b) Check the top in particular, as the diagnostic LEDs are occasionally left on.

6. Take dark or bias calibrations as needed. As there are no dark slides for HERMES, these exposures are best taken when the dome is dark.

[1] Typically the system prompts the user each day. The system can also be updated by choosing Commands → Reconfigure from the AAO CCD Loader window.

7. Final spectrograph preparation
   (a) Take a fibre flatfield frame. Use it to confirm that no spectra bleed off the CCD at the top or bottom.
   (b) Focus the spectrograph on both slits.
8. Check the data quality by reducing an arc and flat with `2dfdr`.

8.2 At the start of the first night

> This section is for advanced users only. If you have not done this before, seek help from AAO staff before proceeding.

1. **Setting up a Field**. Once the pointing and astrometric calibrations are done (these are performed the first night 2dF is back to the telescope) a field can be set up for the calibrated plate. See Section 12 for details about how to configure a field with 2dF.

8.3 At the start of every night

1. **Telescope Focus**. Once it is dark, a star is centered in the Focal Plane Imager (FPI, see Section 10.3) to focus the telescope (described in Section 10.4).

8.4 Science Observing

1. If changing fields, check that all required calibrations have been taken with the current field before tumbling to the new field.[2]
2. In the Telescope Control window, select the source for the next observing positions, typically Config Plate File. Clicking Load position from file should update the position boxes on the left hand side of the window.[3] See § 9.2: Telescope Control
3. Check with the night assistant that it is safe to slew the telescope, then click Commence Slew and Track in the same window.
4. While the telescope slews, exchange the field plates using the Tumble button in the Positioner Control window. See § 9.3: Positioner Control.
5. Once the new plate is in position, and the spectrograph slit exchange has completed, take the required calibration frames (usually an arc and a flat). While these frames read out, there is generally time to check the seeing and centre the field using the FPI camera. § 9.4 describes how to set up the runs.
6. Confirm that the ADC is tracking — look for "Tracking" under the ADC in the Main Window.

[2] In general it is safe to take calibrations while slewing, but large slews do affect the fibre throughput, probably at the $\lesssim 5\%$ level.

[3] Alternately, particularly for non-configured locations such as standard stars, the position information can be given directly to the night assistant.

7. After calibrations are complete, ask the night assistant to set up the guiding.
   - If the Night Assistant asks for the plate rotator, find the Clone Rotation to NA button which is under the Rotation tab in the Positioner Control window (§ 9.3).
   - Usually the field is acquired straight away by the Night Assistant. If not, it may be necessary to acquire with the FPI as described in § 10.3: Acquiring Fields with the FPI.
8. Once the Night Assistant confirms that the telescope is guiding, start the science frames. § 9.4 describes how to set up the runs.
9. Finally, **do not forget** to start the positioner configuring the next plate.
10. Once the science frames have been taken, ensure that the visiting astronomers copy the data from the telescope location (Section 7.5) into a working directory so that they can reduce the data.

8.5 At the end of the night

During the observations with the final plate configuration, the gripper gantry MUST be moved over the plate. There is a small source from the gripper camera that needs to be blocked

1. Stop the ADC tracking — look for "Stop Tracking" under the ADC in the Main Window.
2. At the end of the night, the night assistant will take care of putting the telescope away.
3. If you wish to take additional calibrations, such as darks or biases, they can be started and left running. See Chapter 13. Make sure to tell the night assistant how long the calibrations will run.

8.6 At the end of the run

Taking the data away from the telescope. Ensure that the visiting astronomers have copied their data so that they can take it away with them (§ 7.6: Taking away data).

Chapter 9

The Observing GUI

The observing GUI or "control task" that manages the instrument is called `tdfct` for the "Two-Degree-Field Control Task". The basic software is shared between 2dF+AAOmega, HERMES, SAMI, and KOALA, so it may be familiar for existing users.

Typically, the control task is brought up by the AAT technicians before you arrive. If it is not running, it is necessary to check with the afternoon tech before starting it.

9.1 Main Window

The Main Window is primarily just a status display. Sub-windows that control various parts of the observing system can be brought up using the more buttons under each subtask box in the middle of the window.

Other useful items in this window:

Messages The bottom portion of the window is the primary message readout for the system. Error messages and a log of recent activity is written here. The text of all error dialogs are also printed here (with a red background).

Reset Tasks The Commands → Reset menu item is used to reset tasks. The Recover option is used to try to bring the software into a known state. Individual tasks can be reset using the By Task button. See the troubleshooting manual or talk to your Support Astronomer or Afternoon Tech if you need to do a reset.

Exiting The File → Exit menu item is used to exit the control task and shutdown the observing system.

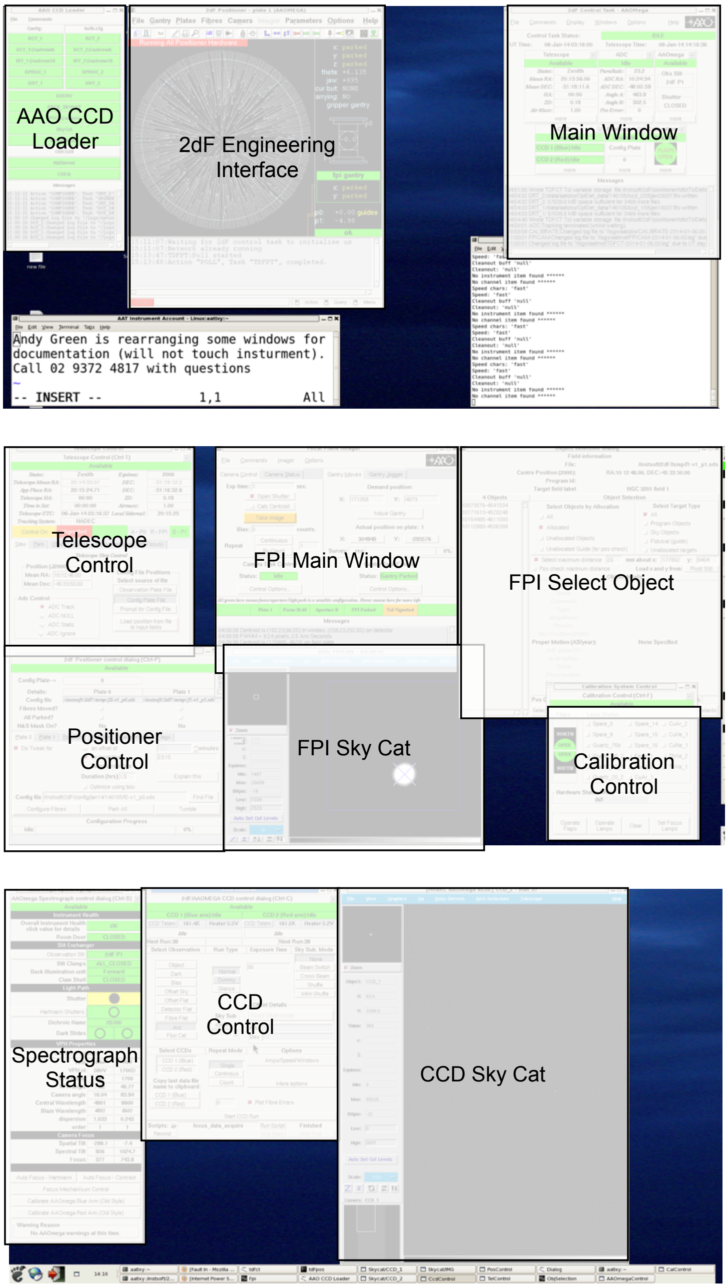


Figure 9.1: *To simplify using the TDFCT GUI, it is recommended that the windows be laid out in a standard way so that buttons and tools are always easy to find from one user to the next. Note that screens are shown stacked rather than side by side.*

9.2 Telescope Control

The telescope should not be moved/slewed without first checking with the night assistant.

The Telescope Control Window is used to move the telescope and telescope focus. Usually,

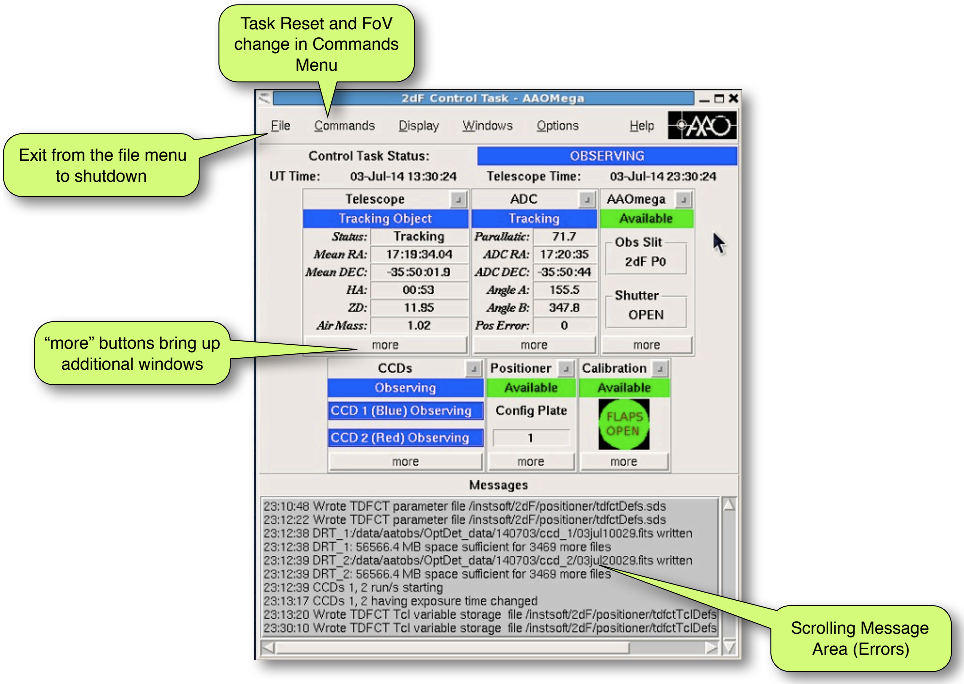


Figure 9.2: *The Main Window of the User Interface.*

this is used to load coordinates of the field configured on one of the observing plates, and slewing the telescope when ready. It is also possible to offset the telescope and change the telescope focus using the other tabs.

The window also provides status information on the telescope's current position.

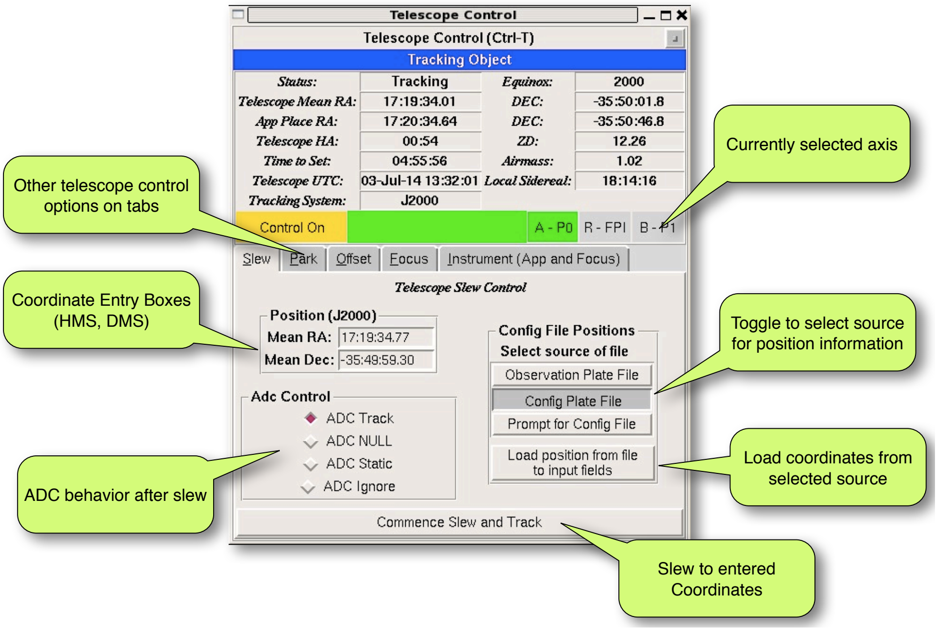


Figure 9.3: *The telescope control window.*

9.3 Positioner Control

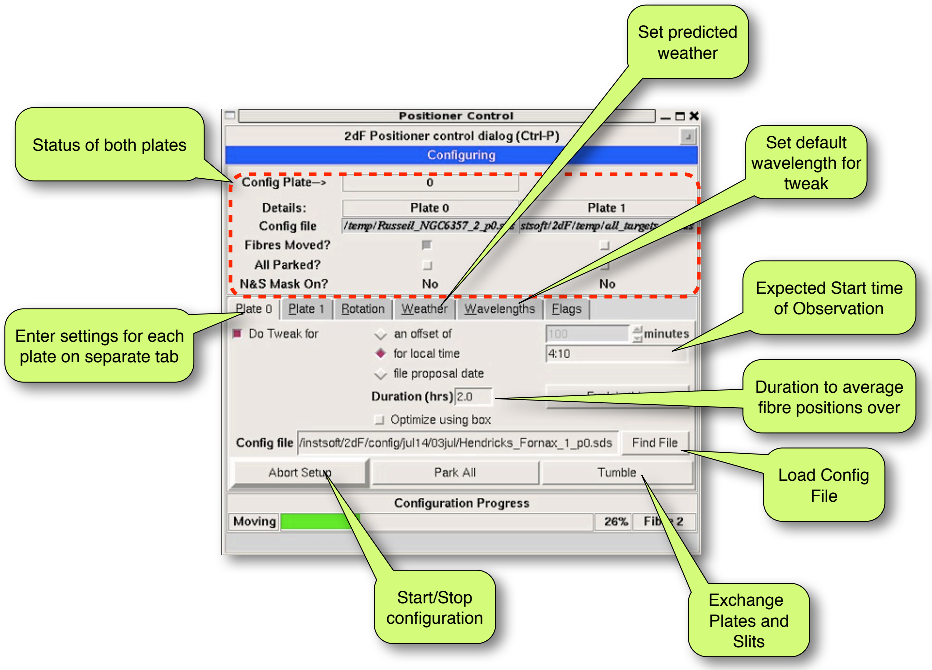


Figure 9.4: The positioner control window.

The Positioner Control window is used to set up the configuration of a field plate. The top half displays the current status of both plates. Tabs on the bottom half provide independent configuration settings for each plate, as well as shared weather and default wavelengths for optimising fibre positions as separate tabs. The final tab allows certain special options to be set.

9.3.1 Plate 0/1 Tabs

A tweak should almost always be performed to ensure fibres are correctly placed for the exact time and conditions of the observation. In addition to the settings here, the current settings on the Wavelengths and Weather tabs will also be applied when Configure Fibres is pressed.

9.3.2 Rotation

Both plates have rotators to improve guiding. The night assistant will adjust the plate rotation as necessary. This tab includes the option Clone to Night Assistant, which provides the widget at the Night Assistant's console.

9.3.3 Weather

The Weather tab contains configuration options for the weather to be assumed when positioning fibres.

The Weather Gathering Toggle chooses between

- Automatic on Setup will load the current conditions from the AAO's Met Station when starting a configuration.

- Using dialog will use the currently entered values in the boxes below when starting a configuration.

Fetch from weather system will load the current conditions from the AAO's Met Station into the boxes above (only available when Using Dialog is selected above.

9.3.4 Wavelengths

The Wavelengths tab is used to configure the default wavelengths for optimising the fibre positioning.

Spectrograph Default Wavelength sets the wavelength that fibres which have not already been assigned an optimal wavelength in the FLD file will be positioned for.

Autoguider The autoguider wavelength sets the wavelength the guide fibres will be positioned for, and should be left set to 5000 angstroms.

The third box (typically displaying 2000) is not used.

9.3.5 Flags

The Flags tab contains settings for controlling the behaviour of the positioner. Most useful here is the last button on the right, which displays a green tree. Unselecting this button will cause the robot not to park unused fibres, useful if trying to quickly configure a field with only a few allocated fibres.

9.4 CCD Control Window

Data acquisition is controlled via the CCD Control window (Figure 9.5).

Observation Type

A series of select buttons determine the observation type. They are:

Object Take a regular science frame of the target(s).

Dark Take a dark frame.

Bias Take a zero length frame (flushes the detector, then reads it out as normal.)

Offset Sky Used for an offset sky frame (for sky subtraction and/or throughput calibration).

Offset Flat This is used for twilight flat-fields (it might also be used for a dome flat, but make sure to keep a log!)

Detector Flat This is used for flatfielding the detector response. Warning: This type of observations moves the slit unit! To achieve correct illumination for these data, see § 13.2.2: Detector Flat Fields.

Fibre Flat This is the standard "flat-field". These files are used in the data reduction to find fibre tramlines (spectra) across the detector, and also to take out variations in response with wavelength.

Arc The standard wavelength calibration frame. The lamp to use is selected after the Start CCD Run button has been pressed.

Flux Cal This identifies the frame as having a flux standard in it. For 2dF, the software will ask you to identify which fibre the flux standard is illuminating.

The observation type is included in the FITS header `OBSTYPE`, and as a binary table extension to aid the data reduction software. The keyword is set as shown in Table 9.1.

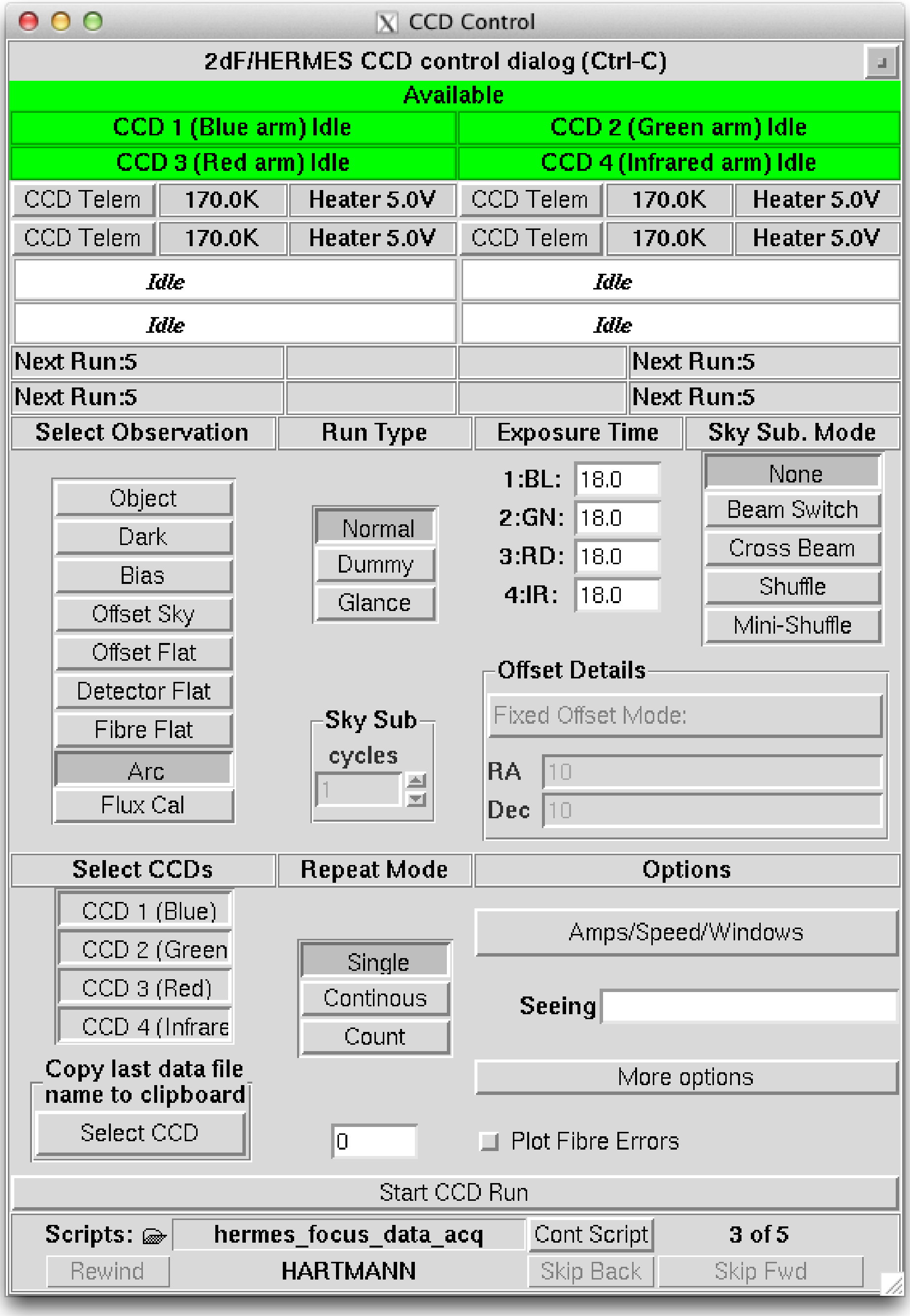


Figure 9.5: The HERMES CCD Control GUI

Run Types

Next, the type of run can also be selected.

Normal A normal run is taken. These data are archived and stored in the regular data directories.

Dummy These data are written to a separate dummy directory, and are not archived.

Glance In this case, the CCD readout is displayed on screen, but not saved.

Exposure Time

The exposure time is set separately for each channel in the 4 boxes in seconds. The tab

Table 9.1: *Observation types and corresponding FITS Header types.*

Type	OBSTYPE
Object	MFOBJECT
Dark	DARK
Bias	BIAS
Offset Sky	MFSKY
Offset Flat	SFLAT
Detector Flat	DFLAT
Fibre Flat	MFFFF
Arc	MFARC
Flux Cal	MFFLX

key will autofill all four boxes with the value in the first box, if the same exposure time is to be used.

Select CCDs
Each toggle button enables/disables the corresponding CCD (arm). Typically, all should be selected.

Repeat Mode
The Repeat Mode selection can be a Single frame, Continuous frames (until manually stopped) or a Count number of repeats. The number is set in the box below Count

Options

Amps/Speed/Windows Brings up a separate window with options for selecting CCD readout amplifiers, windows, and read speed.

Seeing Allows the user to enter the seeing value, which is written to the data file header.

Plot Fibre Errors (2dF Only) When selected, this causes a plot to be displayed upon starting an observing sequence which shows the difference between the physical location of the fibres on the plate and the actual location of the targets. The difference is the result of atmospheric affects not accounted for by the 2dF corrector.

Object Name
This box can be used to set the object name. Note for 2dF and SAMI, this will be set automatically (but can be overridden after starting an exposure in the CCD Run/Wait dialog box.

Start CCD Run
Starts the requested exposure. If the requested frame requires lamps, a box will appear where the specific lamps required can be selected. Calibration flaps, if needed, will automatically be closed (and opened at the end of the exposure, unless they are requested to be left closed.)

Scripts
The final section of the CCD Control window provides the scripting interface which is described in Chapter 17: Scripted Operations.

9.4.1 CCD Run Wait Dialog

After starting a run, the CCD Run Wait dialog box will appear. This includes options for changing options for the current run.

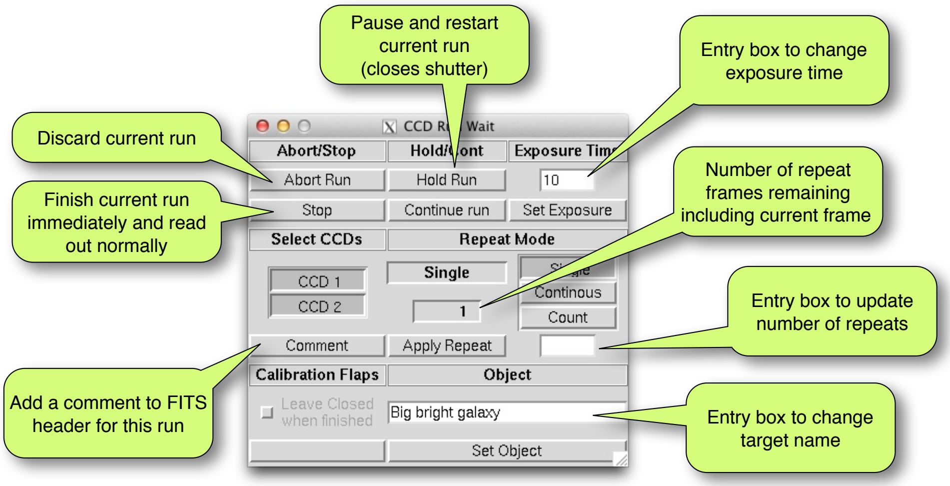


Figure 9.6: The CCD Run Wait dialog box, which allows changing of settings for the currently exposing run. This image is for AAOmega, which is the same as for HERMES, except all 4 CCDs will be available.

Abort/Stop Abort Run and Stop both end the current exposure immediately. The latter will read out the data as normal, but the former will simply discard the data (useful if a mistake has been made in setting up an exposure).

Hold/Cont Hold Run and Continue Run pause and continue an exposure by simply closing the shutter and stopping the exposure clock. Useful for pausing during passing cloud. Note, however, that cosmic rays and dark current will continue to build up even while the shutter is closed.

Exposure Time The total exposure time can be changed by entering a new value and clicking Set Exposure.

Repeat Mode The number of remaining repeats is shown in the grey box under Repeat Mode. This includes the current exposure (the number is decremented *at the end of readout*—"1" means the last frame is currently exposing/reading out). The number of repeats can be changed by entering a number in the corresponding white box, and clicking Apply Repeat.

Comment can be used to add a comment to the header of the current frame.

Calibration Flaps For calibration exposures, it is possible to change whether the calibration flaps will be opened after the exposure (really only relevant for 2dF, where the flaps take some time to operate).

Object Finally, the object name (for the header) can be changed by typing a new name in the box and clicking Set Object.

9.5 HERMES Spectrograph Control

The HERMES Spectrograph Control window provides both the interface for re-configuring the spectrograph as well as a current status display.

Instrument Health panel displays the overall readiness of the instrument.

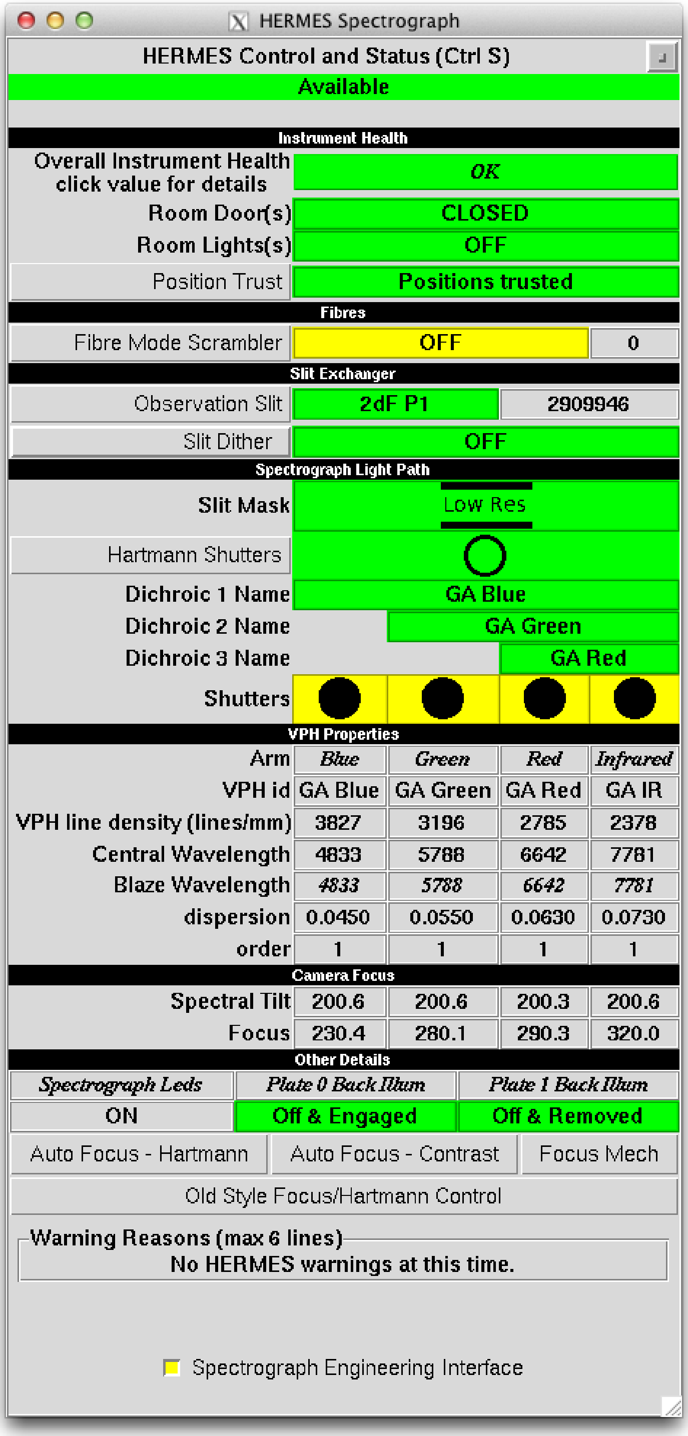


Figure 9.7: The HERMES Spectrograph control interface.

Fibre Mode Scrambler button allows the user to turn ON / OFF the fibre mode scrambler. For this switch to work, please ensure the mode scrambler is correctly wired to 2dF.

Observation Slit button selects which slit is in the observation position (independently of the 2dF tumbler).

Slit Dither button allows the user to turn on slit dithering (usually only needed for Detector Flats).

Hartmann Shutters button reveals a menu for manually closing and opening the Hartmann shutters used for focusing.

VPH Properties panel displays the wavelength and dispersion settings for each channel. These are fixed in HERMES.

Camera Focus panel displays the current Spectral and Focus (piston) settings for each arm.

Other Details panel shows the position of the Back Illumination slits and indicates if the Spectrograph LEDs are ON/OFF.

Auto Focus - Hartmann button starts the focus script which carries out a series of ARC calibration exposures with the Hartmann shutters.

Auto Focus - Contrast button starts the focus script which carries out a series of FLATFIELD exposures at various focus steps.

Focus Mech button opens another window, which allows the user the save and update focus settings.

Spectrograph Engineering Interface toggle button opens another window with the Engineering Interface for manual spectrograph settings. This is reserved for Expert Users only.

9.6 ADC Control

The ADC Control window provides control of the atmospheric dispersion corrector, and a status mimic. Although the ADC has its own control window (see Fig 9.8), it is usually controlled with the Telescope Control windows **SLEW** page as follows:

ADC Track — The ADC will track with the telescope.

ADC Null — The ADC will set to a null position at which it has no effect.

ADC Static — The ADC will be slewed with the telescope but will then be left at the fixed position, not generally a very useful option.

ADC Ignore — The ADC will not be moved.

When slewing the telescope to a new position from the `tdfct` user interface, the ADC 'track button' on the telescope control sub window should be illuminated (the default on startup). In this mode the ADC will automatically follow the telescope when the slew is initiated.

The ADC mimic shows a black line at the parallactic angle and the two dispersion vectors. The orientation of the mimic is such that north is at the top going clockwise through east, south and west just like a compass. The parallactic angle will point towards the zenith so for a field in the south west the parallactic angle should indicate the north-east and the dispersion vectors should be symmetric about the parallactic angle.

If the telescope is moved, say from the Night Assistant's console, the ADC will attempt to follow the telescope in one of two modes, for large changes of telescope position (greater than 5 degrees) the ADC will correct its position in normal slew mode, going to its new position via its index marks; this may take a few minutes. For short moves (greater than a few arcminutes but less than 5 degrees) it will attempt to correct its position using a slew in quick mode, where it slews to a new position without going via its index marks. Note however that after several (6?) quick slews the ADC software may decide that it should check its index marks anyway, and use a normal slew to correct its position.

Figure 9.8: *ADC (Atmospheric Dispersion Corrector) Control window.*

For normal observing the use of the ADC should be almost transparent, with the ADC slewing with the telescope each time the observing field is changed through the night. The use of the ADC becomes more important, however, when observing standard stars. In particular, after pointing the telescope to the position of the standard star, the ADC will use a normal slew to update the ADC position. The next stage of a standard star acquisition is to offset the telescope by up to a degree to position a star down the chosen guide fibre; at this point the ADC should correct its position using a quick mode slew taking only a few seconds.

During the final stage, where the telescope is moved to offset the standard star from the guide fibre to a spectroscopic fibre, the ADC should not be moved as it will affect the position of the standard star. Normally the offset at this stage will be small (less than 5 arcmin) and the ADC will not shift position. If you are using a large offset, it is possible to simply stop the ADC (using the 'stop ADC' button on the ADC sub window) before making the offset; this makes no difference for the short duration of a standard star exposure.

9.7 Status Mimic and Engineering Interface

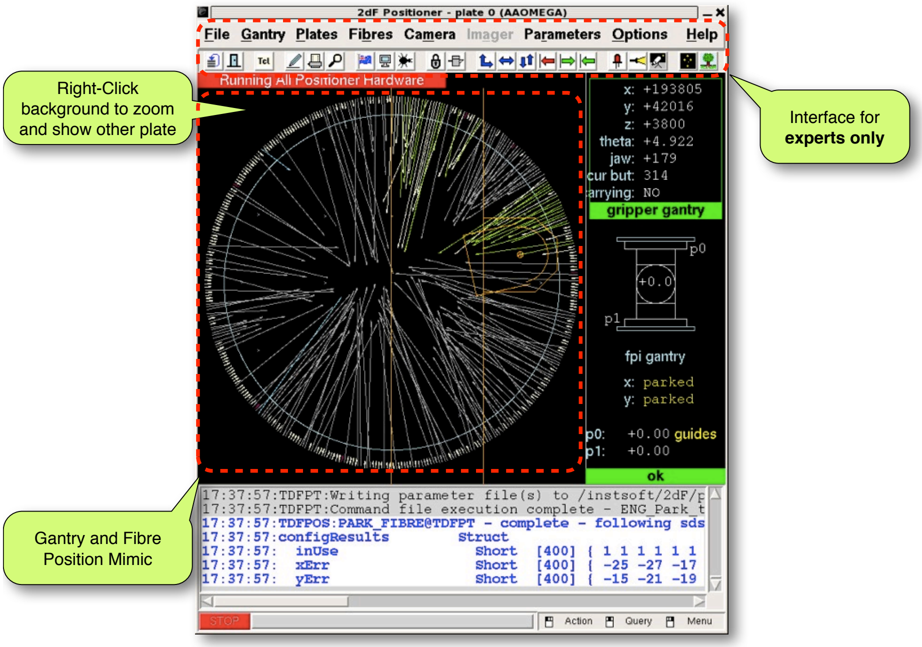


Figure 9.9: *The 2dF Status Mimic and Engineering Interface.*

Incorrect use of the 2dF engineering interface could cause serious damage to the robot. For regular users, this is a status mimic only. Only the actions described below should be executed by the user.

The currently displayed plate corresponds to the gantry highlighted in green on the right side of the display: gripper gantry is the configuring plate, fpi gantry is the observing plate. The other plate can be shown by right clicking in the black background and selecting show other plate.

Chapter 10

Using the Focal Plane Imager

The focal plane imager, or FPI, sits between the field plate and the sky, and has cameras both for looking at the sky, and for looking at the plate. It is used to determine the astrometric calibration used by the 2dF robot to accurately place fibres on astronomical objects of interest. It can also be used for a myriad of tasks requiring an imager, including field acquisition, focusing the telescope, measuring the seeing, and general astronomical imaging.

The FPI camera was replaced in January 2020. The ALTA 260 was replaced with Movarian G4-9000. With 2x2 binning, it has a plate scale of 0.37″ per binned pixel. It also has a larger field of view than the old camera and better cosmetic quality.

The FPI interface consists of three separate windows, shown in Figure 10.1:

FPI Main Window [1] This is the main control window for the camera.

FPI SkyCat This is a standard AAO SkyCat window, which is tied to the FPI sky camera, and updates whenever a new image is taken with the FPI.

Select Object This window lists the objects in the FLD file corresponding to the currently configured plate in the observing position. *This window does not come up until requested by clicking Commands → Select Object (and Poscheck)... from the menu.*

Normally, the FPI is parked out of the field of view (otherwise it would obscure the fibres on the plate.) It can be centred in the field or parked using the controls accessed by clicking on the Control Options... button. Unless precision tasks (such as a poscheck) are being undertaken, there is no need to have the FPI survey the plate.

More usefully, a list of the objects in the configured field can be accessed by choosing Commands → Select Object (and Poscheck) from the menu. This brings up the Select Object window. The left side of this window lists the objects matching the current filter. The current filter is set using the tick boxes on the right side of the window. Below the filter options is information on the currently selected object (not necessarily where the FPI currently is). At the bottom are buttons which can be used to control the FPI.

Usually, the most useful objects are the guide stars, which can be filtered using the "fiducial" target filter. Guide stars typically have good magnitudes for FPI tasks like focusing the telescope and checking the seeing. Once an object is selected, use the Goto RA/DEC button to move the FPI into the field and centre it on the selected object.

Images can be taken by setting the options in the FPI Main Window. Guide stars (magnitude 12–14) typically require exposure times of 1-4 seconds for good images. Particularly for focus and seeing measures, exposures of at least 1–2 seconds are necessary to get stable measurements of the seeing. SNAFU stars are too bright for such checks.

[1] When `tdfct` is first started, this window is minimised.

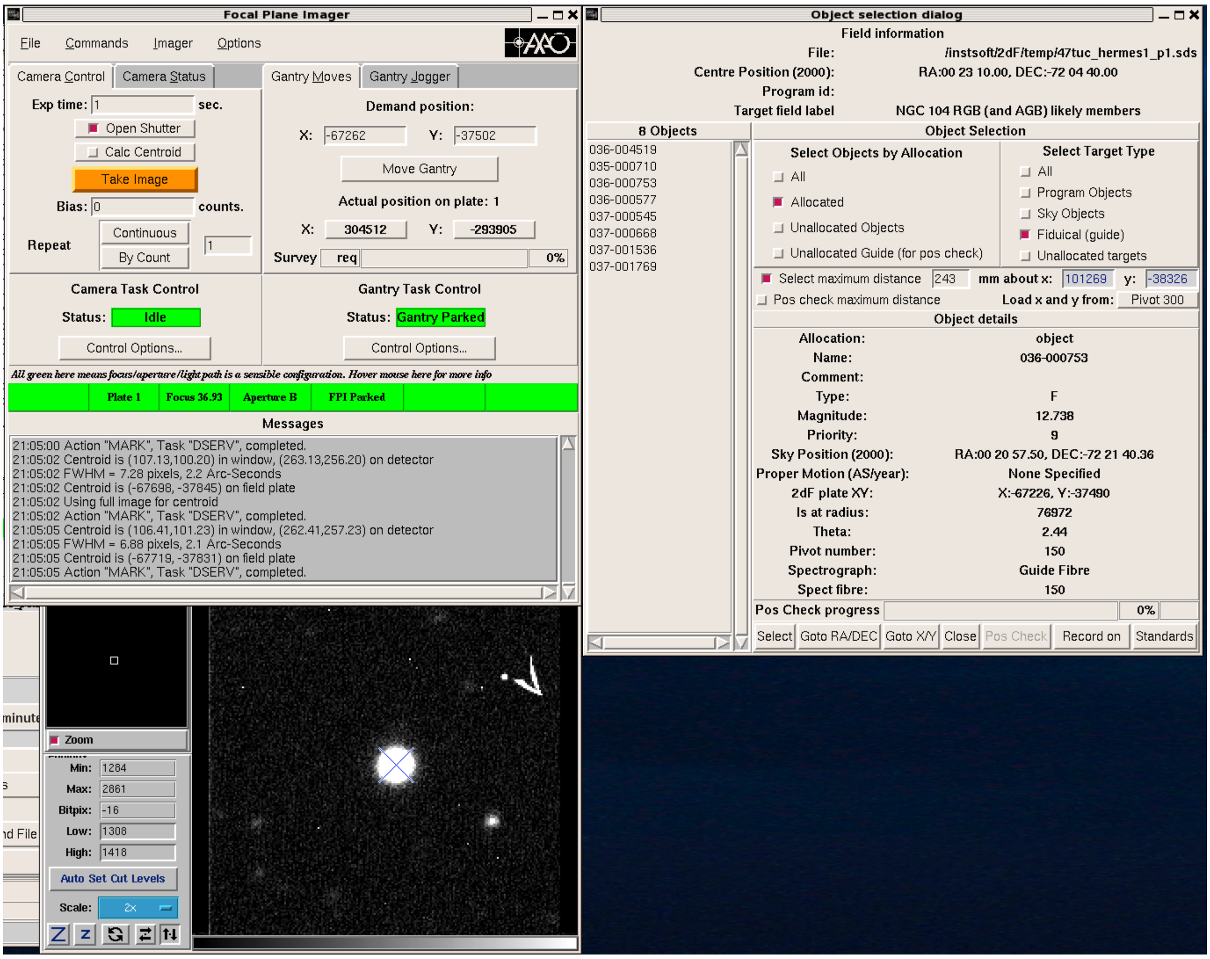


Figure 10.1: The three windows of the Focal Plane Imager Control

10.1 FPI Imaging Options

Continuous Imaging The FPI can be set to continuously take images until stopped by ticking the Continous Imaging box before starting an exposure. The sequence is stopped with stop repeat.

Dark Frame A dark frame can be taken by unticking the Open Shutter box.

Calculating centroids and FWHM If the Calc Centroid box is ticked, the software will measure a centroid either in the whole field of view, or within a centroid box defined by the user. The centroid properties are shown in the scrolling message area of the FPICTL window.

Centroid Box A box can be defined for centroiding operations by `Shift`-left-dragging a box in the FPI SkyCat window.

CCD Readout Window The CCD readout window can be changed (to e.g., get a larger field or decrease the readout time) using the Image → Set Window command in the menu. It is generally advisable to centre the window.

To set the window and the binning options, select *CCD Readout Window*, set binning to 2x2, set the window to 400x400 (in binned pixels), press the *Centre Window Field* field button, and then press apply.

To recover the full unbinned window, set the binning to 1x1, press apply and then press reset.

10.2 Checking the seeing

With a star is in the FPI field of view, it is possible to measure the seeing (or more exactly the FWHM of whatever object is selected). With care, the seeing can be checked during HERMES (or AAOmega) readout, as it takes less than 70 seconds (when the astronomer is awake and alert!)

1. Move the FPI to a star of suitable brightness in the field by selecting one from the Select Object window and clicking Goto RA/Dec. Alternately, one can search for a star by jogging the FPI around the field.
2. By default, the software uses the full CCD window to measure the FWHM. Especially in crowded fields, it is necessary to draw a selection box which only includes the object of interest. Shift-left-drag within the image to create a selection box. Typically, the box needs to be at least a few times the objects FWHM to be useful.
3. With the Compute Centroid box checked, take an image of at least 1 second (to average out the seeing). The FWHM of the star will be displayed in the scrolling message area of the FPI Main Window.

10.3 Acquiring Fields with the FPI

The FPI can also be used to acquire an object (place it's light accurately on a fibre button). This is most often used to acquire a field when the telescope pointing model is slightly out. It can also be used to acquire objects such as standard stars or single objects which the field has not been configured to observe.

1. Move the FPI to the position of the fibre of the object to be acquired (typically a configured guide star) by selecting it in the Select Object window[2] and clicking Goto RA/DEC.
2. Take an image and identify the object to be acquired. *In the case of crowded fields, it may be necessary to move the FPI to several objects and take images to determine where in the field the object corresponding to the currently selected fibre appears.*
3. Either:
   - `Control`-click on in the FPI SkyCat window. This will offset the telescope to bring the point clicked to the centre of the FPI FoV.
   - Choose Commands → Offset Telescope to centre star from the menu to use the centroid algorithm to determine the point to offset.
4. The software will automatically take another image once the offset is complete so you can confirm the object is centred. The centre of the image can be marked using the Mark Centre button in the FPI SkyCat Window.

NOTE:

[2]This window disappears when the plates are tumbled. Bring it up by choosing Select Object (and Poscheck) in the FPICTL Commands menu.

When using the FPI, there can be some confusion about the telescope axis[3]. When the FPI is unparked, the telescope will automatically switch to the REF axis. When it is parked or Move cleared the telescope will switch back to the appropriate axis for the observing plate (A=0, B=1). Generally, this is seamless, but can be confusing especially during some operations. If the telescope is in the wrong axis when centring, then the offset will be incorrect. Alternately, if the telescope is not switched to the correct axis for the observing plate, then light will not fall on the fibres on the plate when taking an exposure using the instrument.

In any case, once the telescope offset has completed, another single FPI image is automatically taken; you should check this image to make sure the star is centred.

10.4 Focusing the Telescope

The first setup to do once it gets dark is to focus the telescope. The telescope focus is not fully temperature-compensated (the metal structure of 2dF in particular) so it is advisable to re-check the focus if there is a large temperature change or the seeing improves. Once familiar with the process, it can be done in ~90 seconds.

The normal range of the telescope focus value is **36.0–41.0 mm**.

1. Point the telescope at a suitable star. Guide stars from the first science field are good, although if the field is a long way over a star closer to zenith may be better. The Night Assistant has a list of stars on file and can choose one if needed. *SNAFU stars are too bright (~ 7th mag) to focus accurately.*

2. Move the FPI to either one of the guide stars for the configured field using the Select Object window, or (if using another star), centre the FPI by clicking Control Options → Centre gantry - no survey (under `Gantry Task Control`, right lower part of the FPI control window).

3. Take an image of the star by pressing the **Image** button in the FPICTRL window.

4. Check the quality of the image. You may need to adjust the exposure time, generally 2-4 seconds[4] is suitable for a 12^{th} magnitude star.

5. Select Commands → Focus Telescope from the FPICTRL window menu.

6. Now select the number of steps and the value of the focus offset between them. We suggest 3 steps either side (7 total steps) and 0.2 mm focus offsets. Click OK.

7. The procedure then starts and it automatically drives the telescope through a range of focus values, taking a centroid at each point and fitting a Gaussian to the image profile. A plot is displayed of FWHM vs focus position and a fit is overlaid (see Figure **??**). One can then use the fitted minimum as the new default focus position.

8. If unsure of the focus position, either return to the initial focus or use the displayed minimum, and repeat the procedure with an increased range. Please note that seeing variability may play an important role here, so you may need to modify the values given to the focus procedure. When you are more confident of the right focus, you can decrease the number of steps and the focus offset.

9. The Night Assistant can also set the focus to a value used on a previous night if necessary.

[3]The AAT has three computer defined axes, REF, A and B. Switching between these axes offsets the telescope by a small amount, defined by the APOFF, ostensibly to change between an acquisition camera and an instrument.

[4]The FPI camera saturates at 65,000 counts.

10.5 Acquiring a target to an arbitrary fibre

There are two methods for acquiring an arbitrary target, such as a standard star, to an arbitrary fibre on the plate. The automatic method walks you through the process, but, because it uses a guide fibre for acquisition, the automatic method is not suitable for acquiring extended sources. The manual method can be used for extended sources or unusual circumstances, such as large offsets. Keep in mind that the automatic process does a blind offset, while the manual process will guarantee the offset by using the FPI to centre the object over the desired fibre.

10.5.1 Automatic Method

NOTE:
This method does a blind offset to bring the object from a known position (the guide fibre) to the science fibre. Offsetting the AAT is generally quite accurate, but large offsets may give mixed results. The manual method can provide better acquisition (but obviously is more difficult). The automatic method is *not suitable for extended targets.*

The basic procedure is to centre a standard star in a guide fibre then use a blind offset to put the standard star down a spectroscopic fibre. For this reason the spectroscopic fibre should be as close as possible to the guide fibre (within 20mm = 5 arcmin) if possible, for best results. The default is 50mm (12.5 arcmin), but this is a little large.

1. Inspect the configuration and choose a guide fibre which lies close to program fibres and near the 2dF field center. Using Fibre 200 is best if possible, since it means the spectra will land near the centre of the CCD. One might consider also using the end fibres for radial velocity standards to check for PSF degradation.

2. From the FPI control window choose the *'select object'* item from the commands menu. Click on the *'allocated'* button and on *'all'*. Then select the chosen guide star from the 'pivot' menu and set the *'maximum distance'* parameter to a small value ($\sim$ 20-50mm). This should leave a list of a few star fibres; if there are too many or too few, change the *'maximum distance'*.

3. Click on the *'standards'* button in the bottom right hand corner and a new dialogue box will appear. This is the offsets calculator. Select the guide fibre from the *'select guide pivot'* section and the spectroscopic fibre from the *'select object pivot'* section.

4. Now **enter the RA and Dec** of your standard star in J2000 coordinates (these are the only numbers you have to enter manually) and press the calculate button. Three sets of corrected offsets are displayed in red. The first is the offset in arcsec from the centre of the field plate to the guide fibre. The second is the offset in arcsec from the guide fibre to the spectroscopic fibre. The third (not often used) is the offset from the centre of the field plate to the spectroscopic fibre. Note that the corrected offsets already allow for cos(dec) and other tangent plate corrections.

5. A series of buttons is now activated at the button of the window. The first is *'Slew to object'*. The user should click this while the *'Control telescope'* switch is activated (a yellow/gray toggle button just above the *Slew* button). **This should slew the telescope to center the current field plate on the star**. The next button down the standard star sequence should now be active.

6. Unpark and centre the FPI, a survey in not usually required here. Centre the standard star on the FPI. Move the FPI clear and wait for the telescope axis to revert to A/B from the FPI reference axis.

7. Once the axis is set, click the *'Offset star to fiducial'* button the next element of the standard star button sequence at the bottom of the standard star control. This drives the telescope to place the star onto the chosen guide bundle. The Night Assistant should now centre this star by offsetting the telescope.

   NOTE: This offset can take some time if all of your guide fibres are at the edge of the field plate. The offset can also be rather inaccurate over the full 1 degree and so the Night Assistant may have to hunt a little for the star.

8. Once the star in centered, click the next button along the sequence `Offset telescope to centre star on fibre'. This offsets from the Guide bundle to the chosen science fibre.

9. Once the telescope has settled, press the *'Taken image'* button at the end of the sequence in the control, and follow the on screen prompt to set the standard star identification.

10. Finally, check that the spectrum looks OK and is not saturated.

If the star is to be placed down a number of fibres, the sequence can be operated in reverse by pressing the appropriately labelled buttons on the control GUI. If a new guide fibre is required, then the offsets should be removed to place the star at the centre of the field, and then the control tool can be closed and re-open with a different pivot point selected.

For a different star, the control tool can be closed and the telescope slewed to a new star.

10.5.2 Manual Method

This section is for advanced users only. If you have not done this before, seek help from AAO staff before proceeding.

This method depends on using the FPI to centre an object above a given science fibre. Because the FPI movement is very accurate, large offsets are possible (in theory it should be possible to centre an object above any fibre on the plate with a high degree of confidence and accuracy). However, this also requires that the APOFF is correct for the plate used. If there are any questions, consider testing the sequence on a guide fibre to confirm accurate acquisition. The APOFF could be re-calibrated if needed as part of this sequence.

A strong working understanding of the 2dF system and APPOFFS will help greatly.

1. Have the night assistant slew the telescope to the coordinates of the target to be observed.

2. Select an allocated fibre on the observing plate using the Select Object window of the FPI Camera. Fibres nearer to the centre will be easier to acquire. Fibres up to 1/2 of the plate radius are routinely acquired without difficulty.

3. Note the position of the fibre on the plate in microns, as given in the Select Object window.

4. Survey the plate and centre the FPI gantry. The survey ensures that the FPI is positioned accurately above the plate.

5. Take an image and identify the object to be acquired. Centre the telescope on the object. Take a sufficiently deep image with the FPI to identify surrounding objects, which will make confirmation that the offset later has acquired the correct target (and not a random star which happened to be nearby).

6. Divide the micron positions of the desired fibre by 65 microns/arcsecond, the plate scale to determine the offset. Fibres at positive X and positive Y will require offsets south and west, respectively. For example:

Plate Position of Fibre		Telescope Offsets	
X	Y	DEC	RA
-36761	-14137	565" N	217" E
101391	-38045	1559" S	585" E

7. Ask the night assistant to make the required offset (via the Offsets tab on his or her interface.

8. With the object selected in the Select Object window of the FPI, click Goto X/Y (not RA/DEC[5]).

9. Take another image with the FPI camera and identify the object to be acquired. Depending on the size of the offset, it may not be in the centre of the field. If necessary, use the full window of the FPI camera (Commands → Set Window). Confirm that other nearby objects appear as expected.

10. Centre the object with a Control+Click. Centre it again with a centroid box (shift+drag) and Commands → Offset Telescope to Centre Star. Repeat the latter until the telescope offsets returned are small (displayed in the messages area of the FPI window).

11. If only a short exposure is required, then it is easiest to now move the FPI clear and take the image. Between frames, the FPI can be driven back to the position of the fibre and the centring confirmed.

If a long exposure is required, then it is possible to use the FPI as a poor man's guider. Keep in mind that the AAT tracks very well, and routinely can track for an hour or more without guiding and not drift off of a field. Therefore, the following is really only necessary if one needs to confirm that the tracking is working, or perhaps to confirm a raster sequence or other complex operation.

1. Instead of moving the FPI clear, move it to another position on the plate so that it does not vignette the target fibre (choosing a fibre numbered less than 200 to start will help greatly!). This is most easily accomplished by dragging the FPI gantry image in the engineering interface to a suitable location. Once dragged, right click in the engineering interface to confirm the request.

2. Ask the night assistant to manually change to the axis corresponding to the plate, i.e. A for plate 0 and B for plate 1. Set the FPI to continuous imaging mode, and look for a star. The FPI Gantry Jogger can be used to make small movements to find a star.

3. With a star in the field, stop the continuous imaging mode, turn on the centroid calculation, and take a single image. A cross should appear in the skycat window corresponding to the position of the object.

4. Disable the centroid calculation, and then restart the continuous imaging mode. The cross will remain on the screen at the position of the star in the first frame, so any offset between the star and the cross is due to a tracking error or offset. The night assistant could manually move the star back under the cross as needed.

5. The object should now be centred over the fibre and data can be taken.

[5] Goto X/Y moves the FPI to the actual position of the fibre on the plate, while Goto RA/DEC moves it to the current apparent position considering the atmosphere. We want the arbitrary target to actually be centred over the fibre, hence the choice of X/Y

Chapter 11

Preparing the instrument

11.1 Setting the Proposal ID

At the start of each night, or for each service program executed, it is necessary to appropriately set the Proposal ID within the control task. This is written to the FITS headers, and used in the data archiving system to appropriately determine proprietary periods and access permissions. Therefore it is important that it be set correctly.

The Proposal ID can be set/updated by choosing Commands, Set Proposal ID in the control task Main Window. Options in the Set Proposal ID window should be used as follows:

AAO Visitor Mode Most regular proposals should use this option. Select the appropriate year, semester, and then enter the ID (last 3 digits of your proposal ID) in the box. Click Calculate, and confirm that the Proposal ID shown at the top matches your proposal ID.

Service Mode For service mode observations. This must be set for every service program, so will usually be reset multiple times during the night. Proceed as above.

Calibration For calibration files which are non-proprietary. Relevant for taking darks, biases, calibrations to be shared between service programs, other test data.

Enable Manual Entry Should only be used in special cases. Telescope staff wishing to test the instrument should use this option and enter "TEST" if a more relevant entry cannot be made.

11.2 Focusing the Spectrograph

The HERMES focus procedure uses pairs of Hartmann shutter arc frames to derive the focus values. A pair of arc frames are observed, each with an occulting shutter closed across half of the collimator mirror (left and right half in turn). When the system is in focus, the obstruction in the beam will merely result in a loss of system throughput. However, if the system is not correctly focused, the two frames will project arc lines onto slightly different places on the CCD (moving the line pattern as a whole to the left or the right).

The principle of the focus technique is to measure these shift as a function of position on the CCD, and then adjust the detector position (Piston and Spectral tilts only, the Spatial tilt is not motorized) to minimize the observed shifts.

An analysis script takes as input a Left+Right Hartmann pair, smoothes the images to reduce the impact of bad pixels, cross-correlates 9 subregions of the images, in a 3×3 grid, to determines shifts, and then returns suggested values to adjust the focus.

We recommend running the focus procedure every night, a few hours before observing starts (with the dome lights off). The best focus values can differ between the two HERMES slits, hence the focus should be set independently on both slits. Once the best focus values are set, it usually changes minimally day to day. Below we outline the focus procedure:

1. In the HERMES Spectrograph Control Window (see Figure 11.1), click AutoFocus - Hartmann. The sequence of hartmann exposures will commence immediately after. The exposure time is fixed at a value appropriate for the instrument resolution mode (180sec in nominal resolutions, 300sec for list mask mode).

2. The Automatic Focus window 11.2 will also pop up at the start of the script. This displays the Piston, Spectral tilt and Spatial tilt for all four CCDs for various settings, which are filled in as the focus script proceeds. The Current Position and Settings at Image Capture should be the same.

3. Once the two set of exposures have readout, the calculated pixel shifts will be updated in the Automatic Focus Window. Inspect the suggested new settings and the difference.

4. If the difference in pixel shifts is less than 0.1 then the focus is fine. If not, click the Apply button to move the selected setting to the suggested new value. Clicking Apply Arm will move all mechanisms per CCD, and clicking Apply All will move all CCDs.

5. If the shift was large, repeat the script to confirm the movement has been applied correctly. This is needed as the proposed correction assumes a linear relationship between pixel shift and focus, which is only valid for small focus shifts.

6. At the end of the scrip both hartmann shutters will be left open. If for some reason the focus script was aborted mid-way, ensure both Hartmann shutters are opened prior to taking science frames.

7. Once you are happy with the focus values, select the Focus Mech button from the HERMES Spectrograph Control Window. The Focus Mech Windown will open up as shown in Figure 11.3. In here, select the Save Settings button to save the current focus values for the slit used. A window as shown in Figure 11.4 will come up asking to confirm the settings. Select Save current settings as the new standard. This will ensure the correct settings are applied each time you tumble between slits.

8. Repeat the above steps for the other slit and ensure both sets of focus values are saved. In the HERMES Spectrograph Control Window select the Focus Follows Slit button to ensure the focus values automatically change to the saved values when you tumble between slits.

11.3 Data Quality Checks

Once the instrument is fully configured, it is critical to check the quality of the resulting data. These checks ensure that you will be able to maximise the scientific value of your data. It may be necessary to adjust settings and iterate these checks if everything is not satisfactory.

Focus Arc-lines should have the expected resolution, typically well rounded at the central parts of the detector and elongated at the edges.

Detector Position Check that no spectra fall off the edge of the detector at the top or bottom of the image and that the central fibre is not in-between the 2-amplifier readout boundary.

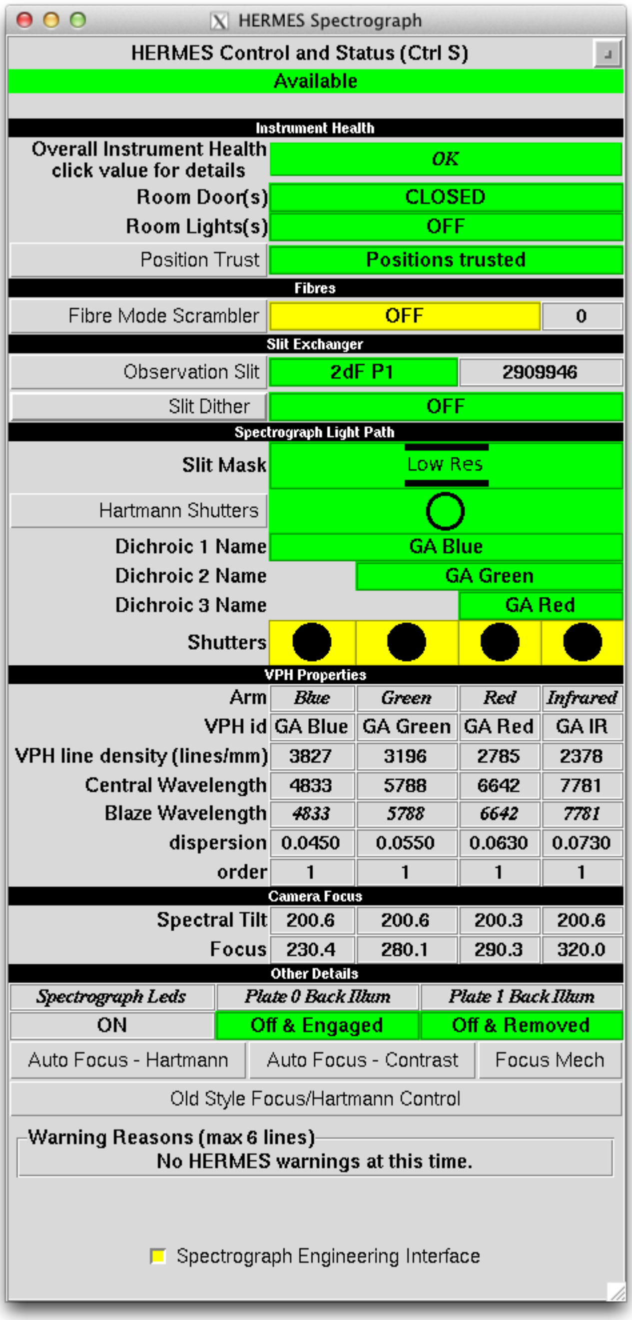


Figure 11.1: HERMES Spectrograph Control Window.

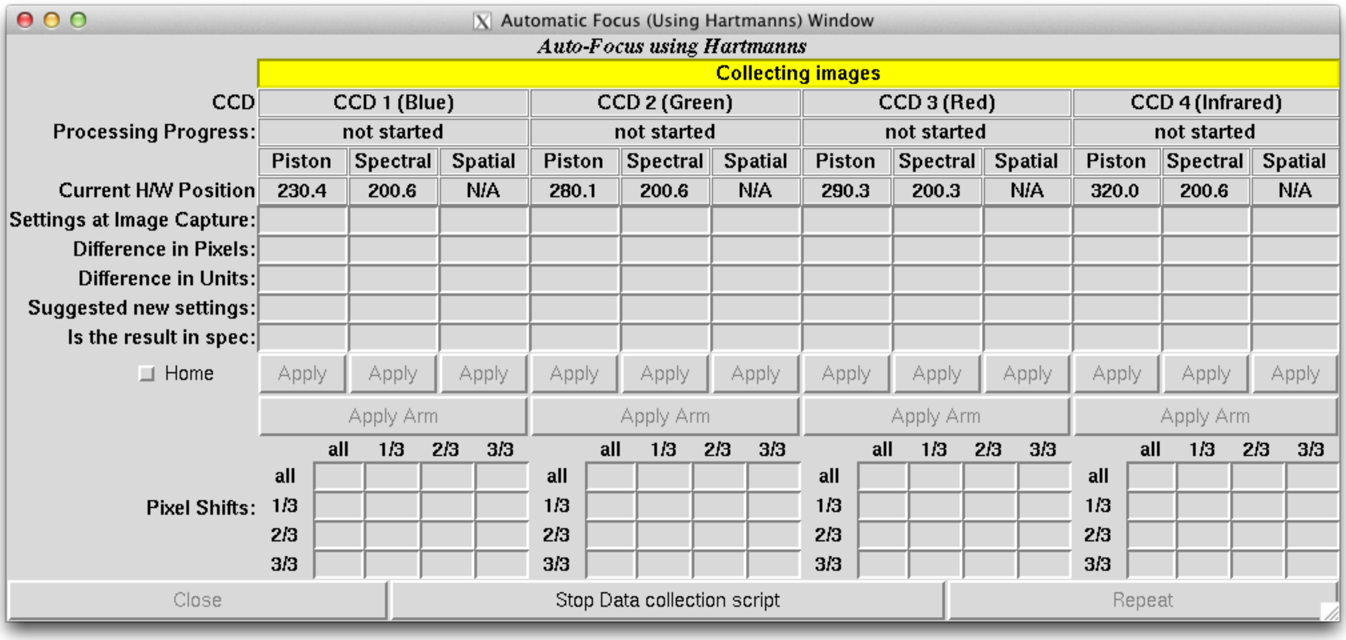


Figure 11.2: *Automatic Focus Window.*

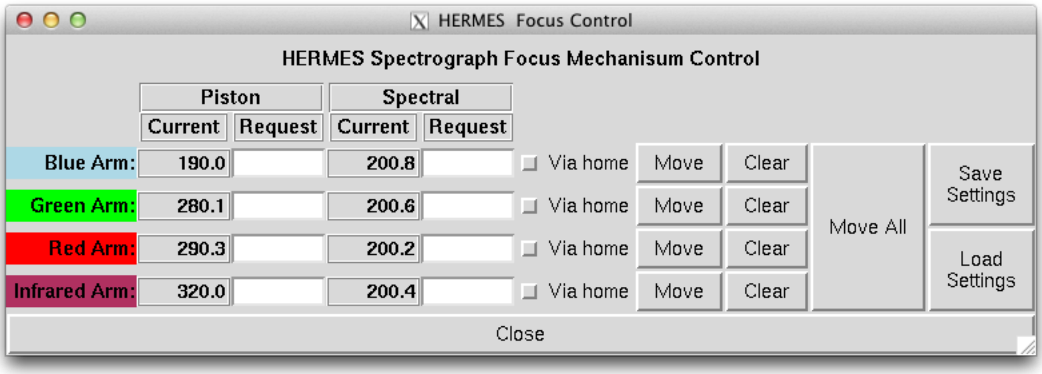


Figure 11.3: *Focus Mech Window.*

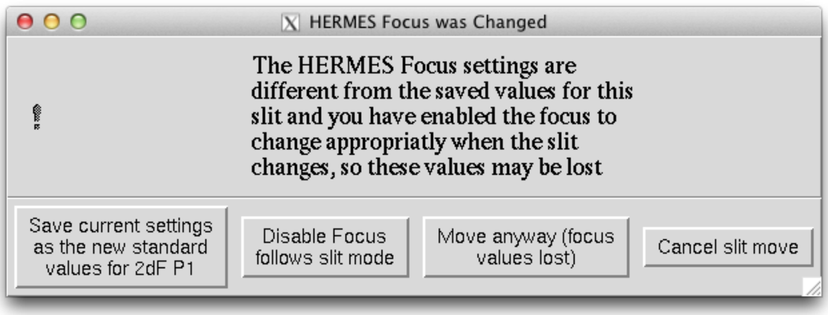


Figure 11.4: *Confirm changes to focus values.*

Detector Defects Check that no detector defects affect key portions of the data. This includes watching out for any light leaks on the image.

Chapter 12

Configuring a Field

Before configuring a field in the afternoon, the instrument must be released to the observers. Check with the AAT staff that no work is being performed on the instrument, and that it is safe to begin configuring.

"Configuring a field" is the process of moving the fibres around in the telescope's focal plane for a new field. As input, this process requires an `.sds` file that is the output of "running `configure`" (see Chapter 6: Using Configure).

12.1 Making `.sds` Files Available

The `.sds` file must be copied to a directory that is accessible to the robot. Typically, the user should copy the `.sds` to a subdirectory of

```
/configs/
```

This directory is available on any of the computers in the control room. *Note*: The subdirectory of `/configs/` must have been created by the account copying the .sds file. Then, on the instrument control computer (`aatlxy`), the file is copied into a directory for the night's observing, e.g., ~2dF`/config/oct13/20oct`.

12.2 Configuring the field plate

Once the `.sds` file is in place, the configure is set up and started using the Positioner window, Figure 9.4.

1. If the plate to be configured is not in the configure position, click Tumble in either the Plate 0 or `Plate 1` tab to exchange the plates.

2. Under the Wavelength tab, set the spectrograph central wavelength. The autoguider default of 5000Å should not be changed except on expert advice.

3. Under the Weather tab, set appropriate values for the weather at the start of the observation. Except for fields configured during the afternoon, the best is to use the Met System values. Select Using Dialogue, then the Fetch button will update the values with the current conditions.

- **NOTE 1:** Write these values down in case of software crashes. If you don't record these values, and have to restart the positioner mid-configuration, you may be faced with a time consuming tweak to positions if conditions change. A convenient log sheet can be found at ~2dF/config/LogSheet_conf.ps.
- **NOTE 2:** If configuring during the day remember to set realistic night-time temperatures, etc. Check the Met system and guesstimate the temperate based on what it was 24 hours ago and the current trend.

4. Select the Plate tab for the plate to be configured.

5. Set the start time (in 24h local time) and duration (in hours) of the observing sequence for the field, which is known as the "tweak".

NOTE:
Tweaking a field does not change the total time a field is valid for (which is fixed by the physics of the atmosphere and 2dF corrector system). It just sets how the software will configure the field to get the most possible light down the fibres over the period observed (however little that might actually be!). Generally, fields are valid for up to two hours, sometimes much less.

---

6. Select the configuration (.sds) file by clicking the Find button and finding the file in the file system.

7. Finally, press the Configure fibres button to start the configuration. The system then:
   - Checks that the configuration (including tweak) is valid — i.e., no fibres will collide;[1]
   - Does a survey of the plate to be configured with the gripper gantry (note, the FPI Gantry cannot be moved while this happens);
   - Moves all the fibres to their new positions (for a full field, this takes 30-50 minutes).

12.3 Hints for configuring fields

12.3.1 Changes in Fibre Status

If, during the course of an observing run, the status of the fibre changes (usual with broken fibres being disabled), then the user may want to re-configure the .sds file. The tdFconstants400.sds file on aatlxy is updated by the 2dF software every few seconds. The version of the file on the configure web site is only updated at 8:30am each morning. If configure is run on aatlxa the updated version will be used. On the user's own computer, the new files will have to be obtained from the following directory.

```
aatlxy:/instsoft/2dF/positioner/tdFconstantsDF.sds
```

Configuring a field without parking unused fibres

The default mode of operation is for the positioner to park all unused fibres in a new configuration. However in some circumstances this is not the behaviour which is required. For

[1] If the requested configuration fails this test, then the robot will not be able to configure the field. It is necessary to go back to configure and either de-allocate the offending fibres, or re-do the allocation. Confirm that configure is using the current distortion model.

example if the new configuration is to observe a few bright stars at the end of the night then the observer might not want to spend a lot of time parking the unused fibres. To change the mode of operation select the flags tab on the positioner subwindow and click on the right hand button (provided with help dialogue) to select the mode where unused fibres will be left in the field unless they are in the way of the future configuration. Remember to unset the flag after doing the configuration (it also automatically resets on the next restart of 2dF.)

Chapter 13

Collecting Calibration Data

Collecting most standard calibration data is fairly self explanatory—one need simply to select the appropriate calibration type in the CCD Control Window (§ 9.5), set an appropriate exposure time (Table 4.2) and start the run. Less straightforward options and more details of the calibrations are described here.

13.0.1 BIAS frames

It is generally a good idea to take a number of bias frames which can be combined to minimize the effect of readout noise. A set of 10 bias frames is the recommended minimum number, up to 30 if times allows. Bias frames are used by the `2dfdr` data reduction software if available, but are not required to reduce the data since `2dfdr` can also do bias-subtraction using the chip overscan region.

Note that the dome should be dark when taking BIAS frames with HERMES.

13.1 Dark Frames

Ensure all lights are turned off in the instrument room and the dome is dark (all lights are OFF, including visitor gallery lights) before taking Dark Frames. HERMES does not have Dark slides as the Bonn shutter are specified to be light tight.

13.2 Flat Fields

13.2.1 Multi-Fibre Flat Fields (FLATs)

Multi-Fibre Flat Fields are taken using the quartz lamp in the calibration unit. This illuminates the flaps below the corrector.

Ensure you test the exposure times needed for your science goals before starting night. See Table 4.2 for estimated Flat Setups and Exposure Times, but **always check** your first few calibration data sets carefully.

13.2.2 Detector Flat Fields

Detector flat fields can be taken with HERMES by using the slit dithering mechanism. When this type of Flat is selected, the slit mechanism within HERMES moves such that the detector is "painted". Note this is a lengthy exposure as the motion of the slit dilutes the light and the amount of flux on the detector is low, especially along the inter-fibre spacing. This exposure is best carried out with the help of AAT Support staff.

If a detector flat is started, ensure that the slit mechanism is returned to it original position before starting the next exposure.

13.2.3 Dome Flats

Dome flat fields are useful for measuring and removing total fibre-to-fibre throughput variations. Flat field screens are located at several positions on the AAT Dome. To take dome flats:

1. Inform the afternoon technician that you want to take dome flats so they can arrange to have the dome open and ready to go in time.
2. Check that the light path is clear—usual culprits are the primary mirror cover and the central dust cover. An obvious sign is if the counts on the detector are too low.
3. Have the technician point the telescope at the dome flat screens and have the lights ON.
4. Start your exposure. Typical exposure times are 30min for a single dome flat, depending on the signal-to-noise ratio of your science.

13.2.4 Twilight Flat Fields

Twilight flat fields are useful for measuring and removing total fibre-to-fibre throughput variations and variations in chromatic fibre-to-fibre responses (although the latter is usually done with a standard Fibre Flat Field).

Twilight Flats can be taken as follows:

1. Confirm in advance with the night assistant and/or afternoon technician that you want to take twilight flats immediately after sunset so they can arrange to have the dome open and ready to go in time.
2. Check that the light path is clear[1]—usual culprits are the primary mirror cover and the central dust cover.
3. Have the night assistant point the telescope approximately 100 degrees from the setting sun (typically about 1 hour east of zenith), and start it tracking.
4. Take an series of Offset Flat runs. Between each, have your friendly night assistant offset the telescope by ~ 60 arcsec to reduce the chance of contaminating all of your flats with a bright star. Once you have the exposure time right, a good rule of thumb is to double the length of each successive run to get approximately constant counts as the twilight fades.

13.3 Wavelength Calibration Frames (ARCs)

Wavelength calibration (or ARC) frames are taken using the lamps in the calibration unit. These illuminate the flaps below the corrector. There are four Thorium-Xenon (ThXe) lamps which can only be turned on simultaneously, which is the default lamps used for HERMES.

Other calibrations lamps that are available for AAOmega (CuAr, FeAr, ThAr, He and Ne) can be manually used with HERMES if there is a special need. However the best wavelength calibration is currently achieved with the ThXe lamps only.

[1] It is in fact possible to take twilight flats with some counts with the mirror cover closed!

Part IV

Data Reduction using 2dfdr

Chapter 14

Basic Reductions

2dfdr is the AAO's generic data reduction package for all of the observatory's fibre based spectrographs. 2dfdr currently has modes that reduce data for a number of instruments including 2dF, SPIRAL, KOALA and SAMI feeds for AAOmega, 2dF+HERMES, and 6dF on the UK Schmidt.

NOTE:
2dfdr is rapidly evolving as more is learned about the various data formats. Therefore, one should regularly check 2dfdr release page for updates:

`https://cloud.datacentral.org.au`

14.1 Install 2dfdr

The software is available as a set of binary executables available for Linux and Mac operating systems. The source code is also available.

Download the software from the 2dfdr release page of the data central cloud.

Unpack the tar file and extract the software to your chosen software directory:

```
laptop> tar -xvz -f 2dfdr-8.04-linux.tgz
```

Then, you should add the executable to your PATH to make it easy to start. This is best done by adding a line to your `.cshrc` or `.bash_profile` file as appropriate:

```
# for csh
set path = ($path /path/to/software/2dfdr_install/bin)
```

```
# for bash
export PATH=/path/to/software/2dfdr_install/bin:$PATH
```

14.2 Set up a Directory Structure

2dfdr should be run in a separate working directory for each set of observations with a particular field plate. A meaningful directory structure for your observing run can save a lot of heartache later on. An example directory structure might be:

```
Observing95june05/
    night1/
        field1/
        field1b/
        field2/
        field3/
    night2/
        field1/
        field4/
```

Note that due to the way the flat and arc frames are used, each independent observation (i.e. with a different configuration of the fibres on the field plate) will require a new directory, even if all you have done is tweak the positions of fibre on a previously observed configuration. Once the AAOmega slit wheel is moved with a change of field plate, a new set of flats and arcs are required for the reduction. Data from multiple repeats of the same field, or for fields that contain some repeat observations can be automatically combined, but this is done after the full reduction of data for each field.

Data from the blue and red arms can be reduced in the same directory, but this is often not easy to work with and so most users create separate `ccd_1` and `ccd_2` sub-directories with blue and red data, respectively.

Reduction using `2dfdr` depends on the use of a file naming convention in which the name has a root that is the same for all files. The root name is followed by a four-digit integer run number. Raw data from the AAT conforms to this convention with names of the form `13apr10001.fits` (for blue, CCD 1), `13apr20001.fits` (for red, CCD 2). Data from the archive also conforms to the convention though the names are changed to `run0001.fts`, etc. Usually only in the case of BIAS and DARK frames, it may be necessary to rename files to the same root in order to combine these calibrations from data taken across several nights.

If you have bias or dark calibration files, these need to be reduced in a separate directory, e.g.,

```
Observing95june05/
             bias/
             dark/
```

The reduced, combined output `BIAScombined.fits` or `DARKcombined.fits` can then be then copied into the working directory of the science data before beginning the reductions.

14.3 Starting the software

Move to your working directory of choice and then the software can be started for koala specific data reduction with the command:

```
laptop> drcontrol koala.idx
```

Note, the `.idx` argument specifies the the instrument specific parameter configuration file to be used. On launch, drcontrol will first look for such a file in the working directory and then in the installation directory:

```
/path/to/software/2dfdr_install/share/2dfdr/*.idx
```

The advanced user may know of alternative `.idx` files more suited for their reduction needs and start with the command:

```
laptop> drcontrol ###.idx
```

In the event that drcontrol is called without an idx argument, the launch will bring up the Front Page window (shown in Figure 14.1) from which you can select from existing data reduction prescriptions. These prescriptions are stored in `.idx` files. Additional configurations are available by ticking the List all idx files box.

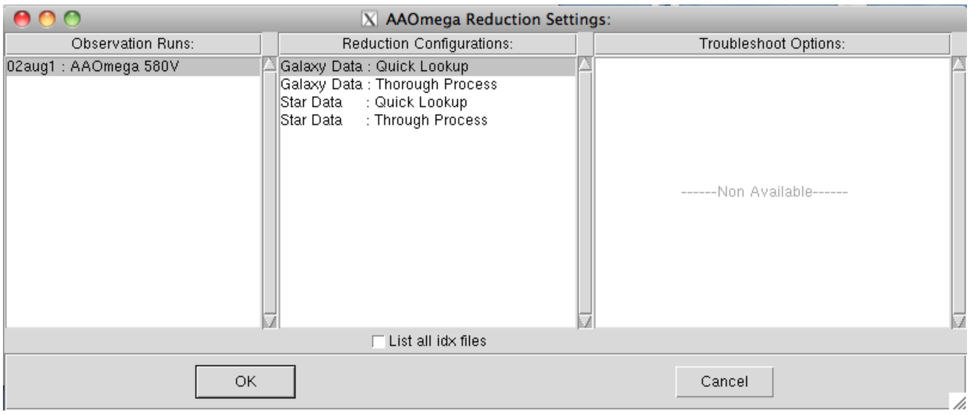


__Figure 14.1:__ Reduction configuration chooser window shown on 2dfdr startup.

Users, if required, can make a copy of these instrument (`.idx`) files in the local directory and modify them to set their own reduction preferences. Not all grating configurations currently have corresponding `.idx` files.

After succesful identification of `.idx` to use, drcontrol brings up the main `2dfdr` window shown in Figure 14.2.

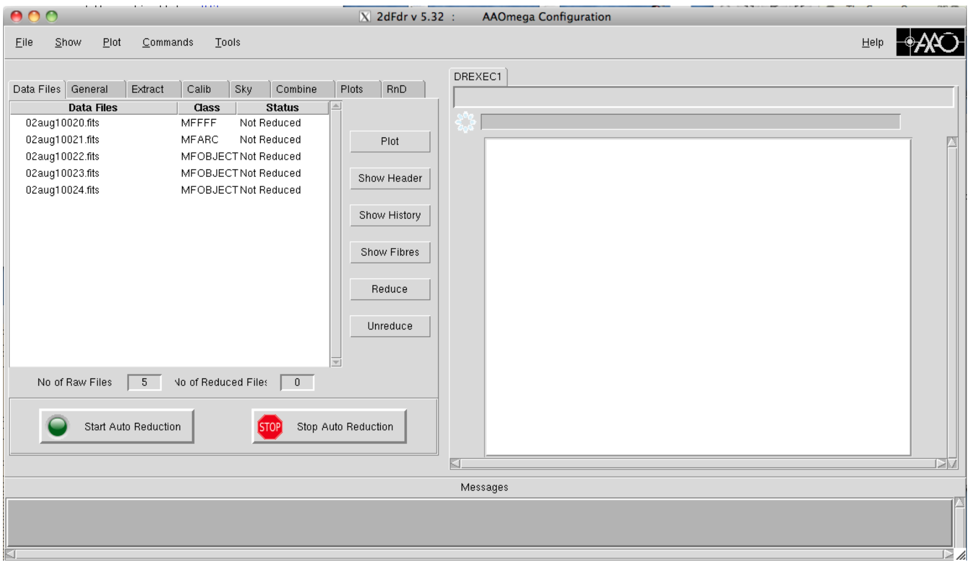


__Figure 14.2:__ The 2dfdr main window.

14.4 Getting Started

The basic files needed to reduce AAOmega data are:

MFFFF — a multi-fibre flat field exposure These exposures are made with a quartz lamp that provides a uniform spectrum. They are used to flat-field the spectral response, and to find the centre and profile of each spectrum.

MFARC — an arc exposure These exposures are made with lamps having various known emission lines. They are used to calibrate the central wavelength and dispersion.

MFOBJECT — one or more science frames The science data to be reduced. This data must be taken with the same setup as the flat and arc frames.

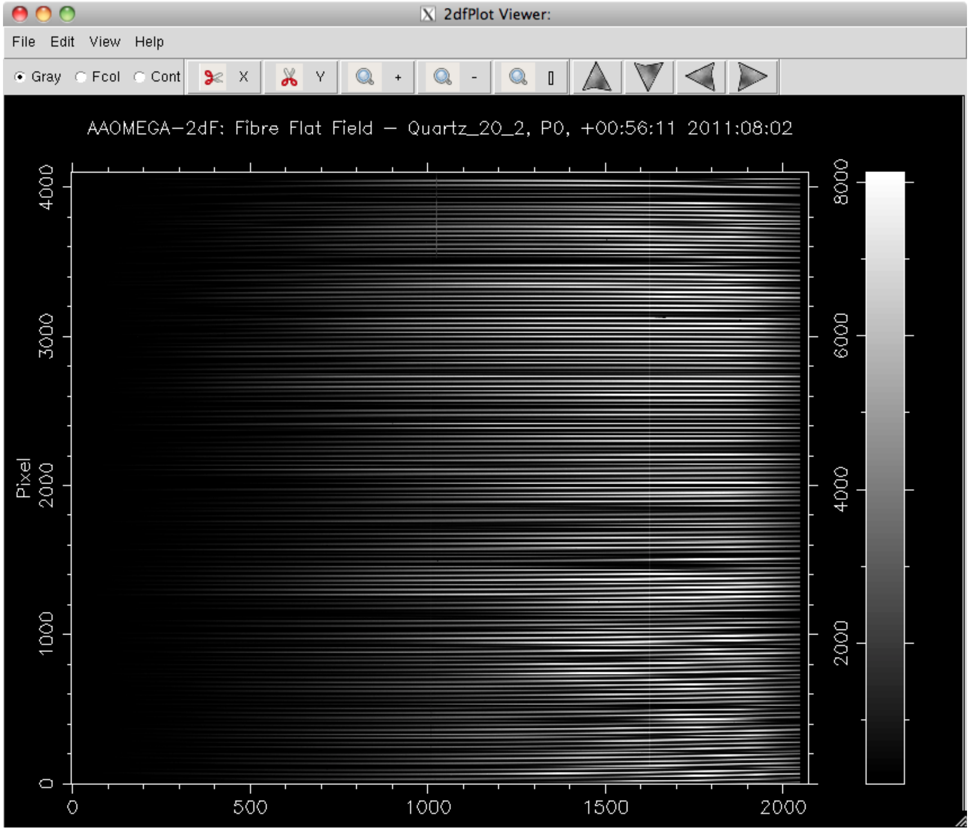


Figure 14.3: *2dfdr Plot window showing a raw AAOmega Fibre flat field.*

Additional frames of various types may be needed to accurately reduce science data, these are the minimum required for `2dfdr` to produce output.

In the main window shows the recognised files in the working directory, their class and their reduction status. Figure 14.2 shows that the first file, Run 20, is file `02aug10020.fits` (which is run 20 for ccd1 from 2nd August). The file is a Multi-Fibre Fibre Flat Field (class MFFFF) frame. The file has not yet been reduced and so the status is Not Reduced.

If we select a file and hit the Plot button to the right of the file information, we can see the 2D image shown in Figure 14.3. This is useful to check that everything looks okay. Note that the full CCD is 2kx4k and so many of the displays you will see during reduction are heavily aliased and will often show strange artifacts which are simply not in the data. Use the Q key to exit the plot window.

The user should be able to simply hit the Start Auto Reduction button, in the bottom left corner, to reduce all the data in the current working directory.

The process runs as follows:

1. Reduce any and all multi-fibre flat field frames
2. Reduce any and all arc frames
3. Re-reduce the flat field frames using the accurate wavelength solution obtained from the arc frame reduction to compute a better average illumination correction
4. Reduce any and all science frames
5. Combine the science frames (if requested in the options)

When the process is complete your working directory will contain a set of *red.fits files which are the reduced data, and the combined data will be in the dateccd_combined.fits file. The formats of these multi-extension files are described in detail in Chapter 15.

If your data overlap in wavelength it is possible to splice them together using the ”Splice Red & Blue” option under the Commands menu.

14.5 Using the GUI

14.5.1 Plotting

When in plot mode, the keyboard shortcuts available are listed in Table 14.1.

Table 14.1: *2dfdr Plot Commands.*

Key	Description
G	Grayscale Plot. A grayscale image of all the data.
F	False colour plot. Same but with false colour.
C	Contour Plot.
$	Magnitude Diagnostic. This plot shows a series of diagnostic plots showing detected counts against input magnitudes. It is useful for diagnosing positioning accuracy and throughput.
I J	Line plot through cursor position in X or Y (respectively).
K L	Histogram plot through cursor position in X or Y (respectively).
< >	Move up/down in zoomed plot, or next/previous cut plot (spectra).
3 4	Move left/right in zoomed plot.
%	Scale to 95th percentile values.
M	Scale to maximum and minimum values.
Z O	Zoom in or out by a factor of two. Note that tramline plots are only zoomed in the vertical axis.
P	Recentre the plot at the current cursor position.
R	Restore the original plot area and scaling.
[ ]	Select corners of a region to expand or zoom in on.
Q	Close the plot window.
?	Display help.
space	Report position and values for current cursor position.

Keyboard commands for the plot window are shown below. This help for the plot window can be recalled using the “?” key from within the plot tool.

14.5.2 Setting Reduction Options

General The General tab covers preprocessing options which are applied prior to extraction of the spectra.

Extract The extraction tab deals with parameters related to the extraction of the fibre traces from the raw 2D CCD frame

Calib The calibration tab includes wavelength and flux calibration options

Sky Sky subtraction options are included on the Sky tab.

Combine Options for combining data from multiple observations.

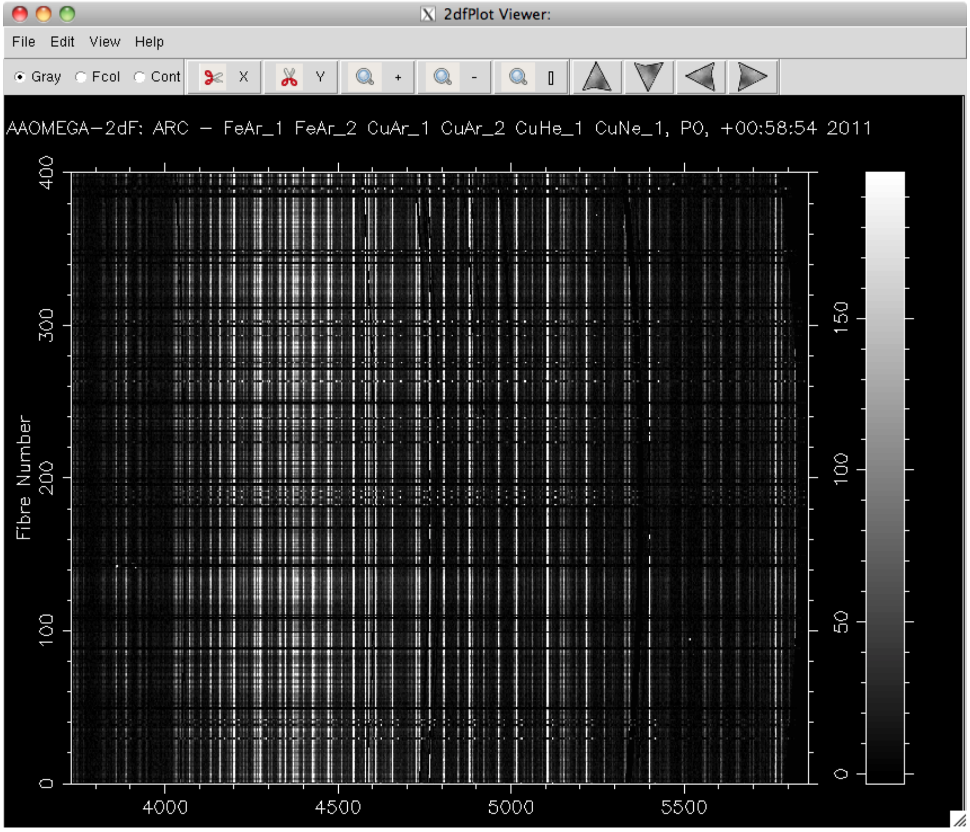


Figure 14.4: *The 2dfdr plot window can display a variety of information for both raw and reduced files.*

Plots Options for the plotting tool, and options to display certain diagnostic plots during reduction.

RnD This tab contains special options which are either still under development or for advanced users. In this tab there is a subtab specifically for Koala (see Fig 14.5). The first parameter listed is the option to correct for any wavelength shift that occurs with time since the arc frame was taken by recalibrating to specific skylines. The remaining parameters are related to either the ”KOALA” specific modelling of variant psf with wavelength (Table 14.2) or the the ”KOALA” background scattered light subtraction process (Table 14.3).

Table 14.2: *KOALA Modelling Variant PSF with wavelength Parameters.*

Parameter	Description
`Column Step Size`	Fit FWHM value at every nth spectral column for all fibers. A value of 1 implies fit for all columns.
`Half Window Size for Column Combination`	Combine +or- this no of neighbouring columns prior to FWHM fits. (0 implies no combination)
`Slice Combination Method`	Combine columns by average (=”A”) or median (=”M”).
`Polynomial order for interpolation fit`	Interpolate, via least squares fit, FWHM values across all spectral pixels with a polynomial of this specified order.

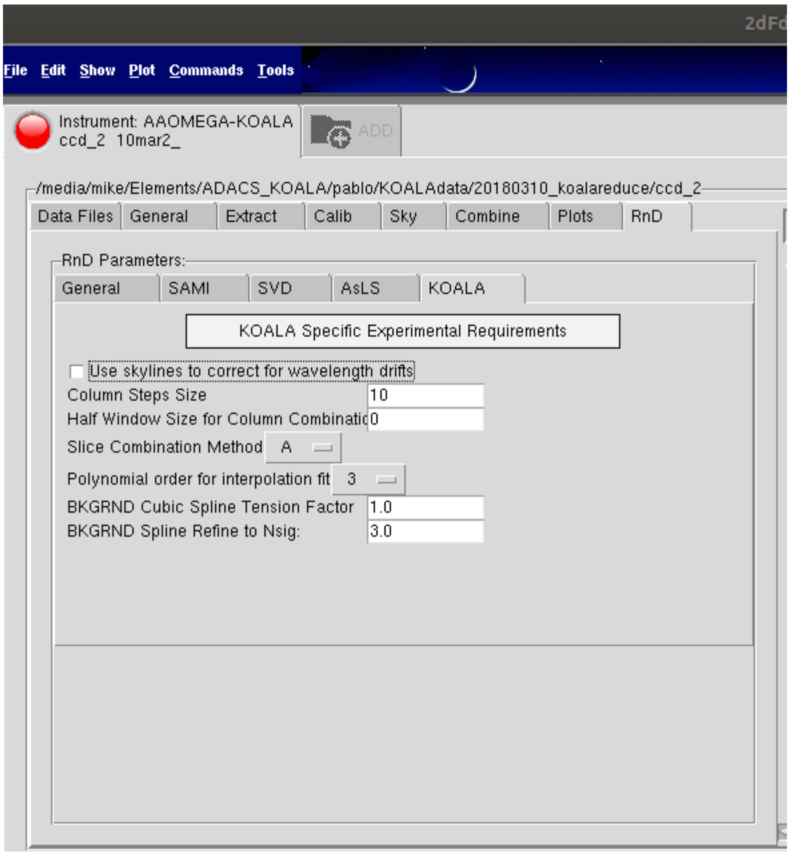


Figure 14.5: *The Koala SubTab of the RnD Tab.*

Table 14.3: *KOALA Scattered Light Removal Parameters.*

Parameter	Description
`BKGRND Cubic Spline Tension Factor`	The tension factor to use for the cubic spline interpolation of spatial scattered light model. NOTE: 0 implies pure cubic spline, 50+ approximates to a piecewise linear model.
`BKGRND Spline Refine To Nsig`	Refine the scattered light cubic spline model so that over subtraction is never more than MN+Nsig*SD of noise.

14.6 Combining Data

Data from multiple observations of the same fields, and also data from multiple observations of separate fibre configurations (usually with some overlap in the targets, which is being performed to increase a sub-set of exposures times) is routinely performed by `2dfdr`.

Typically the data from each camera (red and blue) is combined separately before the spectra are spliced into one continuous spectrum.

Combining of reduced files occurs in 'Auto Reduction' mode when all local object frames have been processed. It can also be done manually using the Commands → Combine Reduced Runs menu item. The `2dfdr` combine algorithm combines data based on either object name or object location. (RA and DEC) That is, fibres having the same name (or location) are added and normalised to produce the output. This is to include all objects, whether they are contained within every frame or only a sub-set of the frames. The combine has the following features:

- Multiple configurations of the same field can be combined together when objects are in common. Note that this can result in more spectra than the instrument can produce in one exposure.
- Only fibre types 'S' (sky) and 'P' (program) fibres are combined. This includes cases in which a fibre has been disabled part way through a field observation, so only good data is combined. Other fibres such as unused and parked fibres have all values set to zero.
- The first spectra will be all those from the first frame in the combine including unused/parked and sky fibres. Any additional spectra will be only sky and program spectra from objects in subsequent frames and not present in the first frame. if the data combined are all from the same configuration there will be no difference in the fibre count.
- All the fibre table extension information is properly propoagated. Additional fibres are numbered beginning from the last fibre of the first frame. So for AAOmega, the first 400 fibres will be from the first frame, and fibre 401 and beyond will be additional fibres from subsequent frames (if any).
- Variances are handled properly.
- An attempt is made to correct for differences in transparency between exposures. This is controlled by the option.

NOTE:
Currently the combined file exposure time is NOT set properly. Exposure time is given in only one place for a file, the value of the .fits header keyword 'EXPOSED'. This exposure time applies to all fibres within the file. When fibres are combined, this keyword is copied from the first frame—no attempt is made at setting it properly.

14.7 `2dfdr` FAQ

Is it possible to look at the data after each reduction step in `2dfdr`?

One can turn on various automatic plot options—the fitted tramlines, the fit to the scattered light background and the profile fits during extraction (with the FIT method), the throughput map and the subtracted sky under the plot tab. If you want to look at the raw extracted spectra (i.e. before calibration/sky-subtraction), select the `*ex.fits` files and use the Plot button to see the extraction once the reductions are complete.

How does the sky-emission-line throughput calibration work in `2dfdr`?

All sky lines are used. Sky-line pixels are identified by plotting the wavelength derivative of the flux—those with large derivatives are identified as sky-emission-line-pixels. Obviously if your wavelength range contains no sky lines (e.g., at high-dispersion in the blue) this option should not be used! In that case twilight flats and/or offset sky frames will be needed. Note, it is only possible to do twilight flats for a maximum of 4 fields a night, two at the start and two at the end, since the fields must be pre-configured in order to take twilight flats, and the flat is not relevant once fibres have been moved, even if the field is reconfigured at a later date.

What does flat-fielding mean in `2dfdr`?

There are three-meanings. The first is the dispersed white-light fibre spectra used to fit the tramlines. This is what is usually referred to as the 'FLAT'. The second meaning is 'pixel-to-pixel CCD flat field' otherwise known as a 'longslit flat'. The third meaning is 'spectral/fibre flat-field', where extracted object spectra are divided by extracted, normalized, white light spectra (this is usually the same data as that used for the tramlines). Given the uniformity of modern CCDs, the 'spectral flat-field' is often sufficient for correcting pixel-to-pixel variations in the CCD.

How can one omit 'sky' fibres which contain objects in `2dfdr`?

Normally this should not be necessary as `2dfdr` takes a median sky, and clips outliers. If you really must, create a file called '`skyfibres.dat`' in the working directory, listing the numbers (one per line) of the fibres you wish to use for sky. `2dfdr` will then use this file, in preference to the headers, when you reduce (or re-reduce) the data.

How does `2dfdr` handle flexure?

AAOmega and HERMES are bench mounted spectrographs in a stable thermal environment. For AAOmega, there is a small shift (~ 0.5 pixels per night) of the spectra due to boiling away of the liquid nitrogen coolant over a night. To retain the possibility of correcting for this the "shift and rotate" option allows the tramline map to be tweaked to the data. For instruments with regular (~ 1 per hour) calibrations, such as 2dF+AAOmega, the effect is effectively mitigated. Users of other instruments may wish to use the "shift and rotate" option.

Can one save `2dfdr` parameter settings?

Yes, via the "File", "Save Configuration..." menu. Alternatively you can create `.idx` files with these settings preset if you are an experienced user. If it is simple case of wanting to use a predefined `.idx` file with a few parameter changes (where the parameter name is known), then a `.idx` file can be written in a few lines as follows:

```
DRC_INCLUDE koala.idx
DRC_OVERRIDE_PAR USEBIASIM 0 REDUCE
DRC_OVERRIDE_PAR COSRAY_MTHD PYCOSMIC REDUCE
```

The `.idx` files are simply tcl scripts that are sourced at the launch of drcontrol and the DRC commands are tcl procedures. The command:

```
DRC_INCLUDE ###.idx
```

instructs drcontrol to use the specified `.idx` file as a base. The command:

```
DRC_OVERRIDE_PAR [PAR_NAME] [NEW VALUE] REDUCE
```

instructs drcontrol to override the specified parameter name with the new value. Note the final keyword "REDUCE" is mandatory.

Can one combine frames BEFORE sky subtraction in `2dfdr`?

No. If you want to experiment with this turn sky-subtraction off completely and do your own processing on the final individual spectra. If you get better results than `2dfdr`, let us know. Most previous efforts at this have failed, and AAOmega has been seen to give 1% sky subtraction. If you care at this level then ask your support astronomer about "Nod and Shuffle" observations.

Chapter 15

2dfdr Output

The 2dfdr data reduction package uses FITS format for input, output and internal manipulation of files. FITS (Flexible Image Transport System) is the nearly universally accepted file format for astronomical data endorsed by the IAU. An overview of FITS with links to reference documents is available at the NASA FITS webpages.

When analysing data from an observing run, one needs to map the combined spectra returned from the reduction task back to individual objects from the input catalogue. All of the relevant information is contained within the combined output file(s).

This page documents the format of FITS files used and written by the 2dfdr data reduction software. First the various file types are explained, and then the internal file extensions are discussed.

15.1 Summary of the 2dfdr Output File Format

The table below gives a summary of the 2dfdr output file content, for either the individual frame *red.fits files or a _combined.fits file. The file is a standard Multi-Extension FITS file (FITS MEF).

Primary image extension
The primary extension in the .fits file is a WxN image containing the number of pixels in each spectrum and N is the number of spectra represented. This is 400 for AAOmega data (392 science fibres and 8 guide fibres). Unused science fibres and Sky spectra, are included in the output file along with the guide fibre spectra, even though the spectra contain no information. In the case where multiple sets of AAOmega datasets, which contained a subset of common objects, have been combined, the format is a little more complex.

First Extension: Variance
The variance extension is also a WxN array identical in size to the primary extension. Each member contains the variance for the corresponding element in the primary extension.

Second Extension: Fibre Table FITS binary table, with N rows, one for each fibre. Each Row contains information for each object such as RA, Dec, 2dF Pivot number and more

Other Extensions The files contain several other extensions which are generally only used when deeper analysis of the data is required. They are not necessarily in order and are accessed by name.

15.2 Output Files

The 2dfdr software creates, reads and writes several file types. Although the system may produce other files depending on version, the common files are described in this section. Not every raw input file will generate all of the output files.

Filenames have the format:

```
DDmmmSrrrrType.fits
```

where:

DD is the day of the month (01, 04, 21, etc.)

mmm is the month of the year (jan, feb, aug, etc.)

S is the number of the arm/camera from shortest wavelength to longest (1, 2, etc.)

Terr is the run number, starting from 0001 each night.

Type is the stage of the reduction (red, im, etc.). This field is empty for the raw files from the telescope.

15.2.1 Raw files

These files are produced by the instrument. They are always read-only to 2dfdr, i.e. they are never modified by the reduction software.

Raw files do not have anything in the Type placeholder. E.g., 13aug20034.fits.

15.2.2 im files

This is the raw file that has

- had bad pixels marked,
- the overscan bias region has been processed, subtracted and removed,
- any cosmic rays have been removed (if requested),
- it has been divided by the long-slit flat frame (if requested), and
- the bias frame has been subtracted (if requested).

Image files have names that are formed by suffixing im to the sequence number of the corresponding raw file. This gives names like 31jan10083im.fits.

15.2.3 ex(tracted) files

An ex(tracted) file has had intensity information extracted from the image file. This is done for each fibre used in the exposure. The spectrum of each fibre is given producing a Wavelength by fibre Number (WxN) array.

Extracted files have names that are formed by suffixing ex to the sequence number of the corresponding raw file. This gives names like 31jan10083ex.fits.

15.2.4 red(uced) files

This is the final reduced file. It contains a Wavelength by fibre Number (WxN) array. It is produced by applying observation type (fibre flat, arc, science, etc.) specific algorithms to the ex(tracted) file.

Reduced files have names that are formed by suffixing red to the sequence number of the corresponding raw file. This gives names like 31jan10083red.fits.

15.2.5 tlm files

This is the tramline map file. It is normally produced in the same step as the ex(tracted) file. It provides the centre fibre positions on the image in pixel units in its PRIMARY array. It may contain a SIGMAPRF HDU array of the same size containing the sigma of the Gaussian profile.

Tramline map files have names that are formed by suffixing ”tlm” to the sequence number of the corresponding raw file. This gives names like `31jan10083tlm.fits`.

15.2.6 combined reduced

This is the result of combining two or more red(uced) files.

`2dfdr` uses the name `combined_frames.fits`.

15.2.7 spliced reduced

This is the result of splicing a pair of AAOmega red and blue reduced files.

`2dfdr` uses the name `spliced.fits`.

15.2.8 combined BIAS

Sometimes called the ”master” bias file, this is the result of combining two or more reduced bias files.

`2dfdr` uses the name `BIAScombined.fits`.

15.2.9 combined LFLAT

This is the result of combining two or more reduced long-slit flat files.

`2dfdr` uses the name `LFLATcombined.fits`.

15.3 File Parts

Each FITS format file contains one or more Header Data Units (HDU). HDUs outside the primary HDU are known as “extensions”. There are three types of HDU: image, ASCII table and binary table. `2dfdr` uses image HDUs for spectra and variance data, and binary tables for fibre information.

The FITS standard requires each HDU to have a header (keyword) section and data section (see Figure 15.1). Each header section contains any number of keyword name, value and comment 80-character records. The purpose of the keyword section is to provide information about the connected HDU data section.

For `2dfdr` purposes keywords in the primary IMAGE HDU provide a description of the observation. The fibre table BINARY HDU header keywords have information relevant for determining the fibre positioning, such as air temperature and humidity.

`2dfdr` output files have a history section (within the primary header) which describes the processing steps used in producing the file. This is contained in FITS keywords with the name “HISTORY”. This information is available within `2dfdr` by selecting a file and pushing the History button.

What follows are descriptions of the individual HDUs used in `2dfdr` output files. Whether a particular HDU appears in a `2dfdr` output file mostly depends on the file type. Each section below has a *Where Used* attempting to document the correspondence.

All `2dfdr` output files have at least the first three HDUs (marked 0, 1 and 2 below). The IMAGE, VARIANCE and FIBRE TABLE also **ALWAYS** appear in this order in reduced files, but in raw files the order may be different, however IMAGE will still be first.

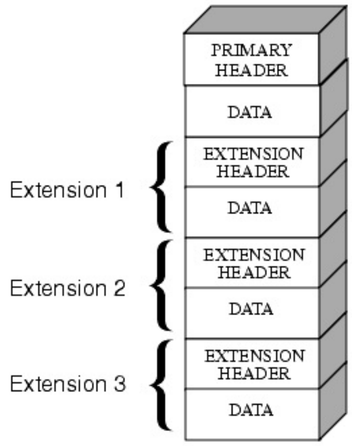


Figure 15.1: *FITS File Parts.*

15.3.1 [0] Primary

A 2-dimension image array holding the raw CCD **image** (raw files), processed CCD image (im files), or **spectral** data (ex and red files). Images are the same size as the CCD. Raw images are slightly larger as they contain the overscan bias region. Spectral data is dimensioned wavelength (number of pixels in spectral direction) by the number of fibres. The data type is 16-bit integer for raw files produced by the instruments, and 32-bit IEEE floating point for all data files produced by 2dfdr.

Where Used: Every file has this HDU. It is written and read by 2dfdr.

15.3.2 [1] VARIANCE

A 2-dimension image array holding the expected image data variance. The array is identical in size to the primary array, and each member contains the variance for the corresponding primary array member. The data type is always 32-bit IEEE floating point.

Values are initially derived from the image data along with values determined from photon statistics, and the detector read noise and gain. The variance is then propagated and adjusted through subsequent steps of the processing.

Where Used: All 2dfdr output files have this HDU. Raw files do *not* have this HDU. It is written and read by 2dfdr.

15.3.3 [2] FIBRE TABLE

NOTE this changes per instrument!

A 2-dimension binary table containing a row for each fibre. Each row describes how the corresponding fibre was used in the observation. The table columns are character data (e.g. the name of the astronomical object the fibre was observing), integer data (e.g. the fibre number) and floating point data (e.g. the object right ascension and declination). Descriptions for all columns are below.

The table appears in raw instrument-produced files where it is created during the observation when it is filled with information output by the ”configure” program. The table is then copied from the raw file to all 2dfdr output files.

There are two types of fibre tables that are identified by their names, either ”FIBRES” or ”FIBRES_IFU”. FIBRE_IFU tables are produced only by the AAOmega IFU instrument and they have slightly different columns to other instruments.

Where Used: Every file has this HDU. It is READ ONLY to `2dfdr` with one exception. The exception can occur when reduced files using different configurations are combined. In this case rows are added to the fibre table.

15.3.4 Fibre Table Columns

The fibre binary table lists, for each fibre, the columns listed in the table below:

Column	**Name**	**Type**	**Description**
1	NAME	String	Object name from the configure `.fld` file
2	RA	Real	Right Ascension from the configure `.fld` file
3	DEC	Real	Declination from the configure `.fld` file
4	X	Integer	2dF field plate X co-ordinate (in microns)
5	Y	Integer	2dF field plate Y co-ordinate (in microns)
6	XERR	Integer	Reported error in X in final fibre placement
7	YERR	Integer	Reported error in Y in final fibre placement
8	THETA	Real	Angle of fibre on field plate
9	TYPE	Character	Fibre type: F-guide, N-broken, dead or no fibre, P-program (science), S - Sky, U-unallocated or unused
10	PIVOT	Integer	2dF fibre pivot number
11	MAGNITUDE	Real	Object magnitude from the configure `.fld` file
12	PID	Integer	Program ID from the configure `.fld` file
13	COMMENT	String	Comment from the configure `.fld` file
14	RETRACTOR	Integer	2dF retractor number
15	WLEN	Real	Wavelength from the configure `.fld` file. This column was added around 2005
16	EXPOSURE	Integer	This column may appear in some combined output files where the combined datasets contained a subset of common objects and therefore exposure times differ for different objects. The column gives the exposure time in seconds for the fibre.

15.3.5 An Important Note on 2dF Fibre-Pivot Number and `2dfdr` Fibre Number

There are two very important, and very different, numbers which one must understand in order to recover the information on which object each fibre was allocated: **Fibre slit position** AND **2dF Fibre-Pivot position**. For the most part there is a one-to-one correspondence between these numbers. Usually the fibre at AAOmega slit position 1 (bottom of the CCD image) will map directly to 2dF Pivot position 1, and 400 will map to 400 (note, 400 is a guide fibre and so maps to a blank space at the top of the CCD image). However, during manufacture or repair of each of the AAOmega slit units, it is sometimes possible for the order of fibres in each of the AAOmega slits to fall out of synchronization with the 2dF Pivot numbering. It is not practical to mechanically alter either position so each of the two fibre numbers (slit position and Pivot position) are propagated in the `fibre table`.

In the primary image (and also the variance array, stored in the first `extension`) the fibre at the bottom of the image, which is the fibre at **slit position 1**, corresponds to the first row in the `fibre table` (the second `fits` extension). The table contains a column entry, **PIVOT**, which gives the **2dF pivot position** for this fibre. This is the *fibre number* seen by the `configure` software. The very top fibre in a CCD image corresponds to the very last entry in the fibre table (which will be an AAOmega guide fibre in the case of a single AAOmega data set). There is ALWAYS a one-to-one correspondence between each spectrum position in the image and the fibre table. There is *typically* a one-to-one correspondence between **slit position** and **2dF pivot position** but with a number of known mismatches and discontinuities which are tracked via the **PIVOT** column of the fibre table.

15.3.6 Examples for Accessing the FITS Fibre Table

This list is not exhaustive.

With configure

One can save a list file (file menu -> ..list) which contains the allocated 2dF Fibre-Pivot number for each allocated fibre. Note, this is the Pivot number for 2dF NOT the fibre number in the reduced 2D spectra file.

2dfinfo

The 2dfinfo procedure comes packaged with 2dfdr. It can be used to recover information on the fibre from the .fits file. The syntax for the command is:

```
2dfinfo file.fits <option>
```

If the <option> is omitted then the list of options is given. To recover the fibre table information one would use:

```
2dfinfo file.fits fibres
```

IRAF

The IRAF/STSDAS package TABLES has a number of routines designed for manipulating tables. A simple example might be:

```
IRAF> tdump combined_frame.fits[2] > output.txt
```

This would create a complete listing of the fibre binary table information and pipe it to an ascii text file. Formatting the output can be achieved with:

```
IRAF> tprint combined_frame.fits[2] columns="NAME,RA,DEC" > output.txt
```

IDL

For users of IDL, the NASA IDL astronomy library has some excellent FITS data access routines.

Starting from a combined FITS frame, combined_frame.fits, one might use the following code extracts to manipulate AAOmega data. Note, there are cleverer (and quicker) ways to perform the operations below with the NASA astrolib tasks, the code here is given as a simple example.

```
file='combined\_frame.fits'

;; Read in the spectral image, store the header information
spec=mrdfits(dir+file\_comb,0,header0)

;; And the variance array
spec\_var=mrdfits(dir+file\_comb,1)

;; Make a wavelength vector, note the use of CRPIX1, which is often not expected by many users.
;; If missed, the wavelength solution will tend to be wrong by half a CCD width
crpix=fxpar(header0,'crpix1')-1.0 ; The -1.0 is needed as IDL is ZERO indexed
crval=fxpar(header0,'crval1')
cdelt=fxpar(header0,'cdelt1')
```

```
wave=((findgen(n\_elements(spec[*,0]))-crpix)*cdelt)+crval

;; Read in the object identification information
fxbopen,unit,file,2
fxbreadm,unit \$
  ,['name','ra','dec','x','y','xerr','yerr','theta','type','pivot','magnitude']\$
  ,id,ra,dec,x,y,xerr,yerr,theta,type,pivot,mag fxbclose,unit

;; And read a copy of the sky spectrum subtracted from the data.
;; Note, for a combined frame, this is the sky spectrum from the first file in the list of combined frames.
;; It is a good representative sky spectrum, but should be used with caution for the combined spectral data.
fxbopen,unit,file,7
fxbreadm,unit,['SKY'],sky
fxbclose,unit
```

15.3.7 Axis Information

Axis information represents the abscissa and ordinate for the image or spectra contained in the file.

The abscissa information represents either the pixel number (image) or the wavelength at the centre of each pixel in Angstroms (spectra). The ordinate information represents either pixel number (image) or fibre number (spectra).

This is NOT a HDU. Instead the information is held in the FITS standard header keyword values CRVALn, CDELTn and CRPIXn, where n is either 1 (abscissa) or 2 (ordinate). FITS keywords CTYPEn and CUNITn complete the description by holding the axis label and units, respectively. These same keywords are used by external FITS viewers (See fv, ds9, etc.) to describe the axis so `2dfdr` output files are correctly handled by these viewers.

Within the `2dfdr` code, axis information is generally held in a one-dimension vector of 32-bit IEEE floating point values. The vector values are constrained to always being linear since only 3 keywords are used. The transformation from FITS keyword values to vector, and vice versa, is hidden in the `TDFIO_AXIS_READ` and `TDFIO_AXIS_WRITE` routines, respectively.

History: The internal vector format comes from when `2dfdr` used Starlink's Extensible N-Dimensional Data Format (NDF). The NDF "CENTRE" axis component was used. This was a vector holding the pixel centre coordinates, with a separate vector for each axis. The NDF axis attributes of LABEL and UNITS were passed to the FITS keyword string values CTYPEn and CUNITn, respectively.

N.B. The functionality of this HDU is nearly identical to the WAVELA Extension, and many of the same issues apply. One of the two should/could (probably) be eliminated.

Where Used: Every file has this information. Within `2dfdr`, axis information is used when plotting files (read only). The abscissa values (wavelength) are set during scrunching and splicing. They are also used to judge wavelengths of interest when matching arc peaks and known wavelength intensities (read only).

15.3.8 WAVELA

WAVELA is a 2-dimension binary table identical in size to the primary spectral and variance arrays. Each element holds the wavelength in nanometres of the corresponding spectral datum. The data type is 32-bit IEEE floating point. The first dimension is in the spectral direction, whilst the second is in the fibre. This extension is written and read by `2dfdr`.

Once established the values in this array NEVER change.

This information is derived original derived by `2dfdr` from keyword values SPECID, GRATPMM, GRATANGR, GRATANGL, CAMANGL and ORDER. The one exception is the original 2df instrument which employs a ray tracing algorithm.

Where Used: All types of output ex(tracted) files and arc red(uced) files have an WAVELA HDU. ??? Why ??? It is specifically removed from flat and science red(uced) files.

N.B. The ability to provide a separate wavelength for each pixel is NOT used. All values in a single column are identical, and the relationship between row values is constrained to be linear. The one except is the original 2df spectrograph where column differences are found. This format is being retained for future development.

N.B. This extension is nearly identical in function to the Axis Information, and many of the same issues apply. One of the two should/could be (probably) eliminated.

15.3.9 SHIFTS

SHIFTS is a 2-dimension binary table holding the polynomial coefficients used to rebin (aka scrunch) data onto the calibrated wavelength scale.

SHIFTS(FIBNO,COEFF) where

- FIBNO is the fibre number, where 1 <= FIBNO <= instrument fibre count
- COEFF is the coefficient number, where 1 <= COEFF <= MAX_SHIFTS (defined in tdfio.inc as 10). That is, there is a set of 10 coefficients for each fibre.

The data type is 32-bit IEEE floating point. Notice this is the file storage type, but normally it is used internally as 64-bit IEEE floating point (DOUBLE PRECISION). This is required by the FIG_REBIN routine (originally from FIGARO).

The name "SHIFTS" is a misnomer since the values represent a polynomial and not a simple shift. It is thought the original algorithm was a shift and this concept was expanded without changing the name.

Where Used: The WAVELA HDU is read and written by `2dfdr`. It is created (written) in two situations

1. During the spectra processing for red(uced) arc frames (see `reduce_arc.f`). These values are used to rebin fibre flat and science frames.
2. During spectra processing for red(uced) sky frames (see `reduce_sky.f`).These values are used to rebin science frames.

15.3.10 THPUT

A 1-dimension binary table holding the fibre throughput. The vector has one element for each fibre. Each element contains a multiplicative factor to account for differences in fibre throughput. The data type is 32-bit IEEE floating point.

The fibre throughput is optionally computed when an object spectra is being reduced using sky fibres in the observation. The results are placed in the object frame's THPUT HDU, and also used to calibrate the object data. This is done when the 'SKYLINE' (or its variants) or 'SKYFLUX' (or its variants) throughput calculation method is chosen.

Fibre throughput can also be computed during the reduction of a sky frame. The values are placed in the sky frame's THPUT HDU, and can later be used to calibrate object frames. This is done when the 'OFFSKY' throughput calculation method is chosen when reducing the object frame.

Object spectra is scaled for fibre differences by dividing by the throughput.

Where Used: This extension is written and read by `2dfdr`.

15.3.11 SKY

A 1-dimension binary table holding the combined and normalised sky spectrum. The vector has one element for each wavelength. The data type is 32-bit IEEE floating point.

The sky spectrum is optionally computed when an object spectra is being reduced. When it is, the sky spectrum is subtracted from each object spectrum, and the sky spectrum values are stored in this extension. Each entry contains the 'typical' sky spectrum used in the data reduction; 'typical' because for a combined frame it is not obvious how the final sky spectrum for each fibre should be represented.

The values in the SKY extension are used during splicing of AAOmega blue and red spectra for what purpose???.

Note: The variance information is correctly propagated, the sky spectrum is not presented here for this purpose.

Where Used: This extension is written and read by `2dfdr`.

15.3.12 TELCOR

A 1-dimension binary table holding the telluric absorption correction used. The vector has one element for each wavelength. The data type is 32-bit IEEE floating point.

Where Used: This extension is ONLY written by `2dfdr`.

15.3.13 SIGMAPRF

A 2-dimension binary array which appears ONLY in the tramline map file. The data type is 32-bit IEEE floating point. Under the assumption that the tramline PSF is a Gaussian function, the sigma value is the estimate of the sigma of the Gaussian. The array has a sigma for each fibre and each spectra pixel. This is currently (Nov2010) being explored by the astronomers with various specific experimental data. Once further confidence is obtained in the derived values they will be implemented instead of the fixed value in the various coding sections including optimal extraction.

Where Used: This HDU is currently ONLY written by `2dfdr`.

15.3.14 DELTA

N.B. This HDU is obsolete. The Fortran code to produce this HDU has NOT been converted from NDF to FITS. FIT extraction does NOT work because in also has not been converted to FITS. See bug report

History: A 2-dimension binary table identical in size to the IMAGE array holding ???. The data type is 32-bit IEEE floating point. This and the SIGMA2 HDU were used for FIT spectra extraction. Both extensions are created when the tramline map is made. The arrays hold ??? sigma and delta of the Gaussian fit to spectra profiles ??? <<– FILL IN HERE! They are used during the spectra extraction but again only when FIT extraction is requested. This extension is written and read by `2dfdr`.

Where Used: No recent `2dfdr` files have this HDU.

15.3.15 NDF_CLASS

A 1 x 1 binary table. Its value was part of the implementation of OO (object-orientated) Fortran. Its use is deprecated.

A 10-character string describing the file type. Known types are given in Table 15.1.

Where Used: All `2dfdr` output files contain this HDU.

15.3.16 REDUCED

A 1 x 1 binary table indicating the file was reduced. If present it contains the single logical value "true". Its use is deprecated.

Where Used: All red(uced) `2dfdr` output files contain this HDU.

Table 15.1: *File Classes.*

NDF Class	Description
MFFFF	Fibre flat field image, raw and im(age)
MFSFFF	Fibre flat field spectra, ex(tracted) and red(uced)
MFARC	Arc image, raw and im(age)
MFSARC	Arc spectra, ex(tracted) and red(uced)
MFOBJECT	Science image, raw and im(age)
MFSOBJECT	Science spectra, ex(tracted), red(uced), combined and spliced
MFFLX	Flux calibration image, raw and im(age)
MFSFLX	Flux calibration spectra, ex(tracted) and red(uced)
BIAS	Bias frame image, raw and red(uced)
LFLAT	Long-slit flat image, raw and red(uced)

Part V

Additional information

This part is a section of the larger 2dF–HERMES manual, which is available from the website.
http://www.aao.gov.au/science/instruments/current/hermes

Chapter 16

2dF Chromatic Variation of Distortion

The prime focus corrector of the 2dF telescope top-end is essentially a 4-element corrector, incorporating an Atmospheric Distortion Corrector (ADC). It is charged with not only delivering the un-vignetted 2degree field at the 2dF field plates, but also creating a flat focal plane, with nearly constant plate scale (projected fibre diameters vary between 2.0-2.1 arcsec across the field plate) and without creating large non-telecentric angles. The subtleties of this have a very real impact on 2dF and AAOmega operations (Lewis et al., 2002, MNRAS)

The first two elements of the prime focus corrector are both prismatic doublets, counter-rotated to compensate for atmospheric distortion. The ADC is actively controlled and has been operating correctly for many years now and regular tests indicate that the ADC correctly compensates for atmospheric dispersion.

16.1 Chromatic Variation in Distortion (CVD)

CVD is a limitation of the design of the 2dF corrector, which was a cutting-edge design for its time. The practical impact of CVD is an effect similar to atmospheric dispersion, but independent of the atmosphere or Zenith Distance. Like atmospheric dispersion, CVD is a differential refraction (with respect to wavelength) effect, but whereas the atmospheric component is almost constant across the field, and so can be largely corrected by prismatic optical elements (the ADC), CVD varies strongly across the field (in a radial direction and with a radial magnitude dependence) and cannot be corrected (in the context of the current 2dF optics).

The problem is that the Point Spread Function (PSF) of the prime focus corrector is strongly chromatic and strongly plate position dependent. The effective centre of the PSF (in terms of its light- weighted position) is NOT a constant as a function of wavelength due to the limits of optical design (for spherical optics the size of those on 2dF) at the time of its construction. This means that the correct position on the field plate at which a fibre should be placed to accept the light from a given target is NOT constant with wavelength. The Configure software has a detailed model for the 2dF corrector and knows where to place fibres to account for this effect, but the user must determine the optimum wavelength to use when placing a fibre. Note that in recent versions of Configure, it is possible to specify up to 9 different central wavelengths to use for different subsets of a target list (i.e. one may want to look at RED and BLUE stars using a different central wavelength for each part of the target list). This option is described in more detail in the Configure input description, Chapter 5.

For a high resolution study, for example stellar radial velocities at 860nm via the Calcium triplet, the solution is obvious, one uses the central wavelength of the observation. However, doing so will mean that little blue light (perhaps for example at the 400nm Balmer break) would fall into a fibre placed correctly for 860nm.

For a low resolution program, the best option may be to configure for the central wavelength and accept some loss of signal at the ends of ones spectra.

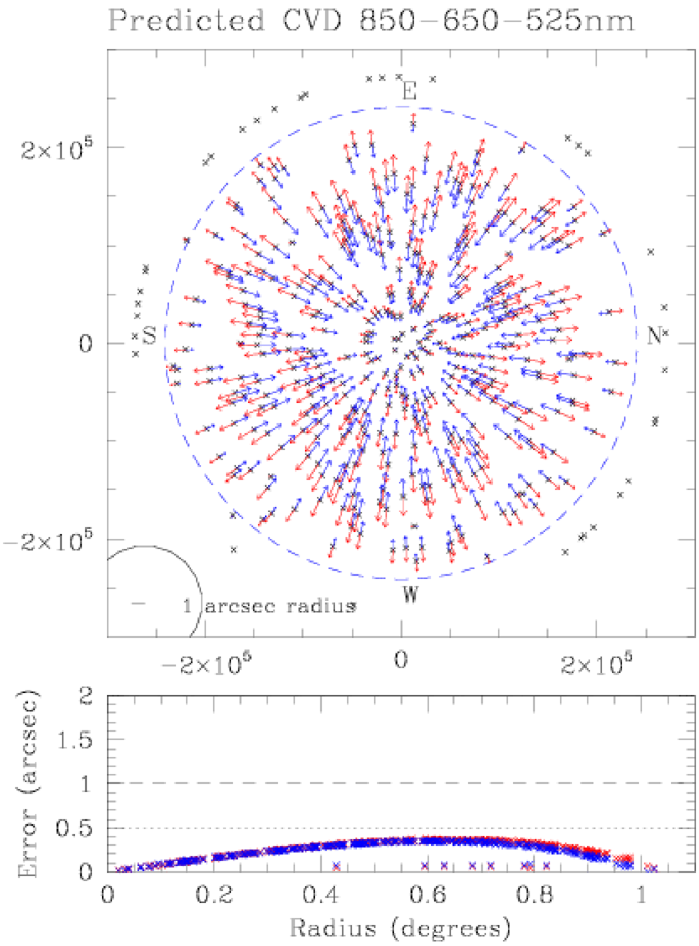
The figure below demonstrates the **predicted** strength of this effect graphically. This figure has been created using the AAOmega Configure software. The same .fld file was configured 3 times, each time with a different configuration wavelength (850, 650 and 525nm here). The .sds files thus created were then investigated and the different 2dF field plate positions that would represent the correct position for each fibre, as a function of configuration wavelength, were extracted.

The figure shows the 2dF field plate with Parked fibres (those not used) around the edge of the field plate. Program fibres are shown on the field plate as a black cross with an associated red and blue vector. The cross marks the 650nm configure wavelength position while the vectors show the offset to the 850nm and 525nm positions. As one can see from the plot, 650nm marks the optimum configuration for this wavelength range, so as to lose the least amount of light across the full spectrum (but giving a deficit at both the blue and the red ends). The scale is given by the 1 arcsecond circle in the lower left corner. The magnitude of the radial displacement is shown in the lower plot. Note that the crosses at about zero correspond to the guide star fibres which are placed at 5000A for the guide camera in all configurations (the small shifts seen here are due to changes in the effective centre of the configuration at the different wavelengths).

A direct demonstration of the **actual** effect of CVD is shown in Figure 5 of Cannon et al. AAO Newsletter Feb 2008, p26-30. This was created using the 'raster scan' technique on a set of observations of relatively bright stars and finding the centroids of the stellar images. The pattern agrees very well with the **predicted** effect shown below.

There is more discussion of both the ADC and the dramatic effects of CVD in Cannon et al. AAO Newsletter Feb 2000, p14-15.

The conclusion one reaches is that, for fibres with 2arcsec diameter, the best fibre placement when the acquisition of the Red and Blue light is key to a project, is usually to place the fibre for a central wavelength and accept losses at each end of the wavelength range. An excellent paper on the magnitude of placement errors of this kind is Newman P.R. 2002 PASP 114 918.



A graphical demonstration of CVD effects in the 2dF prime focus corrector. Note how the effect is most important between 1/2 and 2/3 of the way out towards the edge of the field plate.

16.2 Stale Fields: Differential plate scale and ZD

Why you should restrict your range of Hour Angle during an observation.

A final effect one must consider is the differential plate scale stretch induced by the atmosphere at high ZD. This is also due to atmospheric refraction, but this time differential with respect to position in the wide field (it is close to monochromatic, to first order). It could only be fully corrected for by moving the fibres on the 2dF field plate to new apparent positions. However, this is not practical with 2dF since it would involve re-configuring the entire field.

The atmosphere modifies the true RA/Dec of one's targets to an Apparent observed position. Over a 2-degree field of view, this modification has significant variations in magnitude with changes in HA. What is more, as the Hour Angle changes, the size of the modification changes significantly as a strong function of field plate position. While the full effect is complex shift in apparent position across the field, and depends in detail on where one is pointing on the sky, the effect can (to first order) be considered as three components:

1. Translation of the field centre — taken out by telescope tracking
2. Rotation of the field — taken out by the 2dF field plate rotation mechanism
3. A differential change in the plate scale — Not correctable

The first and second effects are accounted for during observations, but the third cannot be corrected without moving the fibre buttons.

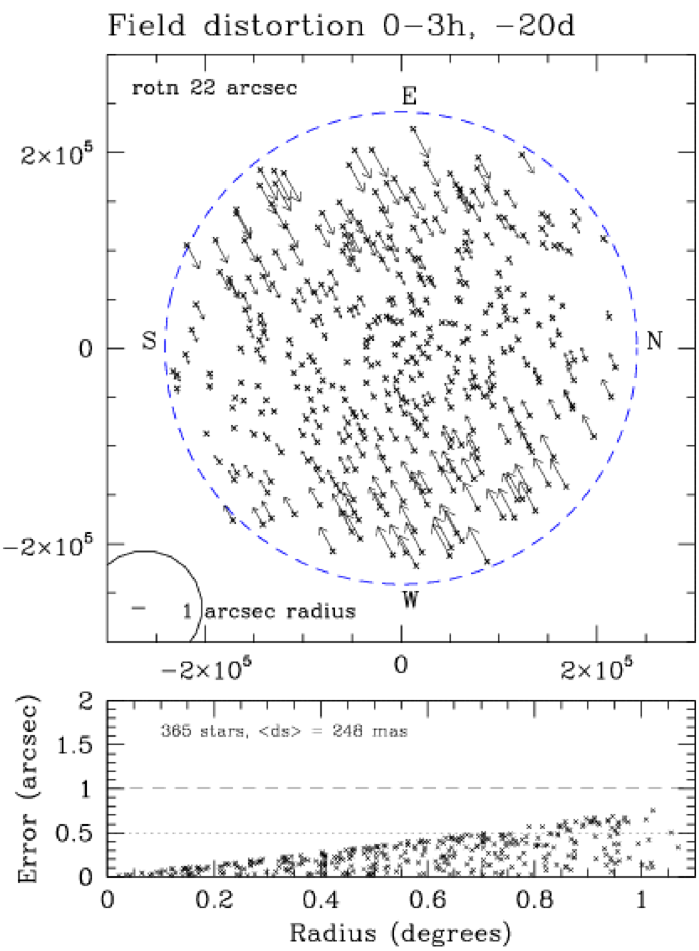


Figure 16.1: *A quantitative indication of a stale field. The arrows in the top panel show the difference between the configured positions of the fibres and the actual location of the targets three hours after the (transit) configuration time. The vectors have been multiplied by a factor of 800 to make them visible. The circle in the bottom left hand corner indicates the size of a ∼ 2 arcsec diameter fibre on the same scale as the arrows. The lower panel shows the lengths of the vectors in arcsec, i.e. the total error, plotted against radial position in the field. The mean error in this case is 0.15" with a maximum value of about 0.4".*

Figure 16.1 shows an example of how a field becomes stale because of the differential change in plate scale. In this case, the field is being observed 3 hours after the time for which it was optimised. When a fibre is away from its target by ∼ 1 arcsec, one is losing ∼ 50% of the available light and the relative losses are greatest in good seeing! Therefore, it is important to make sure that configurations are kept fresh. Figure

The `configure` software and the 2dF positioner know about these effects and so fibres can be correctly configured for a particular HA, but as one moves away from this HA the fibre placements become increasingly incorrect. In practice, the observing software positions each fibre at the time averaged position of the target for the period over which the field is intended to be valid. This optimisation step is called the "tweak".

2dF was designed with a 1 hour reconfiguration (positioning) time so that the effect of the changing plate scale would be minimised. In practice most users find full 2-degree fields remain usable for up to two hours when observed close to the meridian. Smaller fields of view are affected to a lesser degree, and fields at higher zenith distance are affected to a greater degree. Figure fig:field-validity gives an indication of how long a field to be observed at a

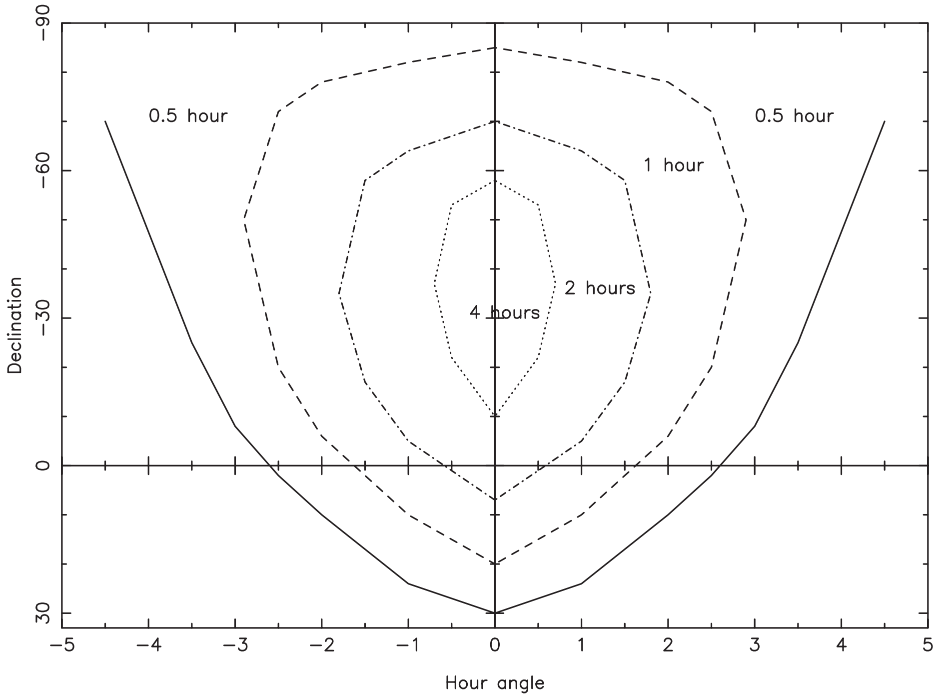


Figure 16.2: *The effect of differential atmospheric refraction at the latitude of the AAT (−31°). The contours show the maximum possible observation times for 2dF fields centred at different hour angles and declinations, if all targets are to remain within one-third of a diameter of the centre of their fibres.*

particular place in the sky will remain valid.

A more thorough discussion of these effects can be found in Newman, P.R. (2002) PASP, 114, 918.

Chapter 17

Scripted Operations

The 2dF control task now implements a simple scripting language. The intention of the feature is to allow the automation of common sequences, both common to the various instruments or on a observer specific basic. These scripts work in all 2dF control task instrument modes (2dF/AAOmega, SPIRAL, SAMI, KOALA and HERMES), but some commands are instrument mode specific.

The scripting language is simple, and does not contain any "programming control" structures (loops, if statements etc). But it is sufficient for many common repetitive tasks, such as running standard observation sequences. If you have a need for complex observing scripts that can't be done with this language, please contact the AAO Software Group who may be able to help you.

As the language is new (August 2013), it may still change a little or be extended a bit more.

This section documents the scripting language and how to use these scripts.

There are two ways of selecting scripts to run. First there are a set of standard scripts which can be selected quickly. Alternatively, you can load scripts from files as required.

17.1 Standard scripts

There are a number of standards scripts. These are available from a menu entry - `Commands->Standard Obs Scripts`. Just select the script of interest from that sub-menu. It will start running immediately, but all these scripts prompt for user input or acknowledgment before running any command which takes an exposure or moves the instruments or telescope.

The sfollowing standard scripts are provided:

Menu Entry	Script	Description
3x3 raster	3x3_raster	Implements a 3 x 3 telescope raster, taking observation at each point. The script prompts the user for the exposure time and telescope offset size. It does a total of 11 OBJECT observations of the specified exposure time. It does an initial observation frame at the centre position, the 9 frames of the raster and an extra one at the centre position.
5x5 raster	5x5_raster	As per 3x3, but implements a 5x5 raster, generating 27 frames.
Take Focus Frames	focus_data_acquire	Prompts the user for an exposure time, and then takes 2 arc exposures, with the appropiate lamps switched on for a standard Hartmann focus frame. The first exposure has hartmann shutter 1 closed, the second has hartmann shutter 2 closed. It then opens both hartmann shutters. This script is used by the new automatic focus procedure available from the Spectrograph Control window

More standard scripts will be added as devised.

17.2 Script file Locations

Scripts (other then the standard scripts above) are located in a defined directory tree found in one of two locations. The program first looks in the directory `obsscripts` in the user's home directory (normally `~aatinst`). It then looks in the sub-directory `obsscripts` of the directory located by the `TDFCT_DIR` environment variable. This later directory is the set of scripts released with the program and any user written scripts placed here will be lost when the program is next updated. The former directory should be used for user written scripts.

Within these directories, there are a number of sub-directories. Scripts must be placed in the appropriate sub-directory to be seen. The table below describes the sub-directories:

Sub-directory	Description
all	Scripts in this directory are available in all 2dF control task instrument modes.
aaomega_2df	Only used when running 2dF and AAOmega
hermes	Only used when running HERMES
ifu	Only used when running SPIRAL
koala	Only used when running KOALA
sami	Only used when running SAMI

17.3 Selecting the script

Scripts are loaded and run from the CCD Control Interface of the 2dF control dialog. The two rows of buttons etc. at the bottom of the window are used. Please see figure 17.1.

Use the open-file button - 📂 - just next to the "Scripts:" label, to open a dialog to enable selection of a script file to run. The resulting dialog (see figure 17.2) shows the list of available files in the standard locations. Hover the mouse over an entry to see the full name of the file (note, a script of the same base name can appear in different directories, and you will need to hover to work out which is which). Select the radio button next to the file name to select that script. Alternatively, you can select “Script Specified Below” to allow you to enter any file name using the file browser below that button.

Select the `Continue` button to load the chosen file. The file is parsed at this point and any errors in the format of the file should be detected immediately.

Warning - if you change the file, you must re-select it to cause it to be reloaded.

17.4 Running the script

Figure 17.3 explains the buttons of the script controls area. One particular thing to watch is that to run a script, you must invoke the `Run Script` button rather then the `Start CCD Run` button just above it.

When the script is actually running, these buttons not active.

A script can be paused at various points. If doing a CCD observation, a “Pause Script” button is available. Any dialog produced by the script and the `WAIT CONFIG` command allow scripts to be paused. If you continue the script after pausing, the next command in the script will be invoked, unless you skip/rewind to another location. A script will also pause if an error occurs whilst running the script.

In rare cases, a script may stop due to an error without the script control buttons being made active again. If you can work out what is triggering this, please report it as a fault. To recover from such cases, invoke `Commands -> Unlock Script` from the control task menu bar.

17.5 The Scripting Language

This section describes the language itself, to enable authoring and editing of scripts.

17.5.1 Basic Syntax

The script language is very simple. A file contains a set of commands, one per line. A command is represented by a token. Tokens can be written in upper or lower case, as desired. Commands can have arguments, which are separated by spaces. Command arguments may be other tokens, quoted strings, integer or floating point numbers. Integer and floating point numbers may be represented directly or via variables.

Some command arguments are lists enclosed in `[` and `]` characters. Items within such lists are comma separated.

A hash (`#`) character introduces a comment. Any text after this character until the end of the line will be ignored.

17.5.2 Observing Commands

Observing commands are used to take CCD exposures. Script commands exist which will execute each of the standard exposure commands supported by the Control Task. Each of the commands listed in the table below take one or more of the following forms:

```
<command>
<command> <time_spec>
<command> <time_spec> <count>
<command> <time_spec> <lamp_spec>
<command> <time_spec> <lamp_spec>  <count>
```

Where:

`<command>` Is the command name, from the table below.

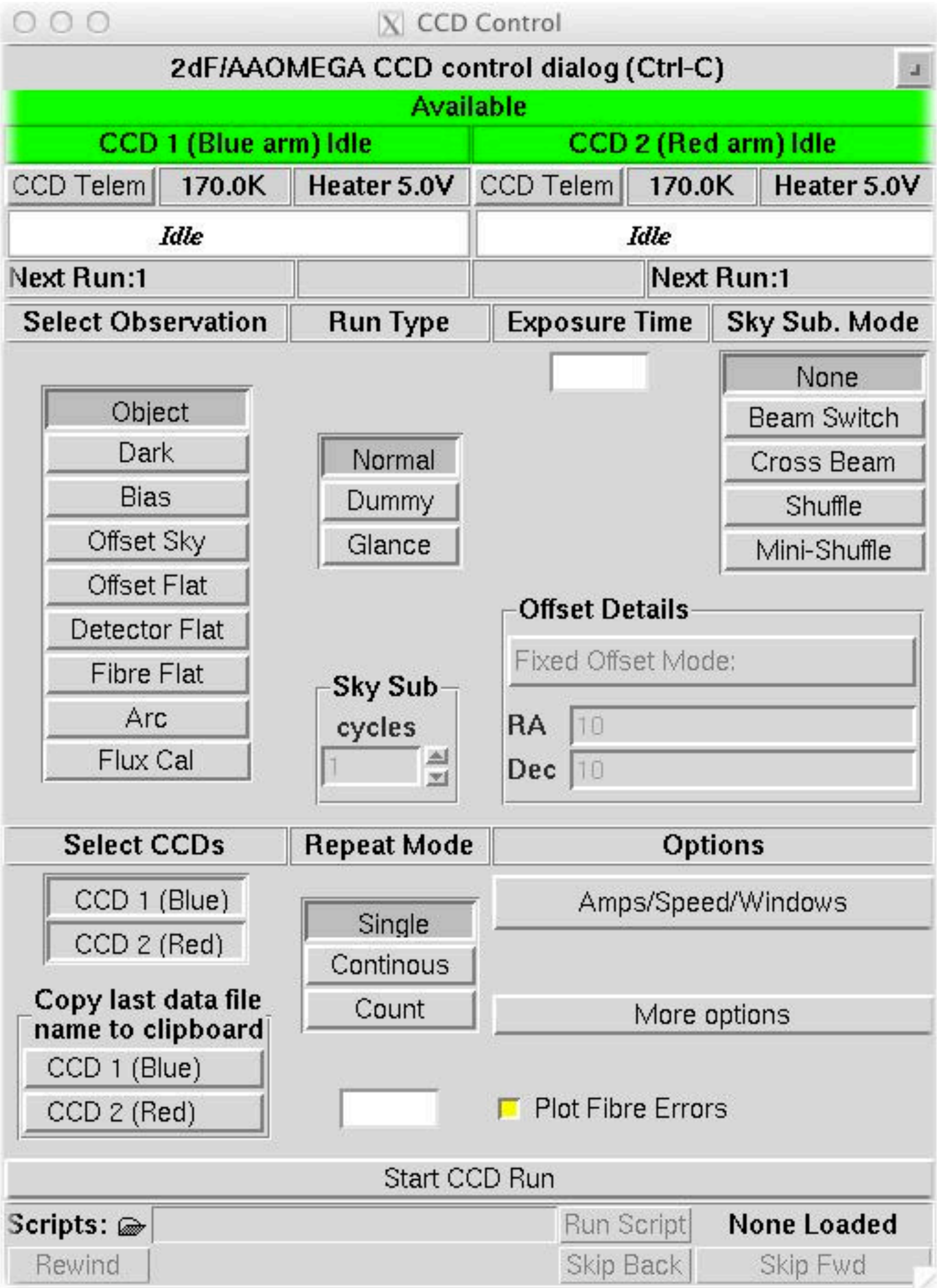


Figure 17.1: *Control Task CCD Dialog - the script control interface can be seen at the bottom.*

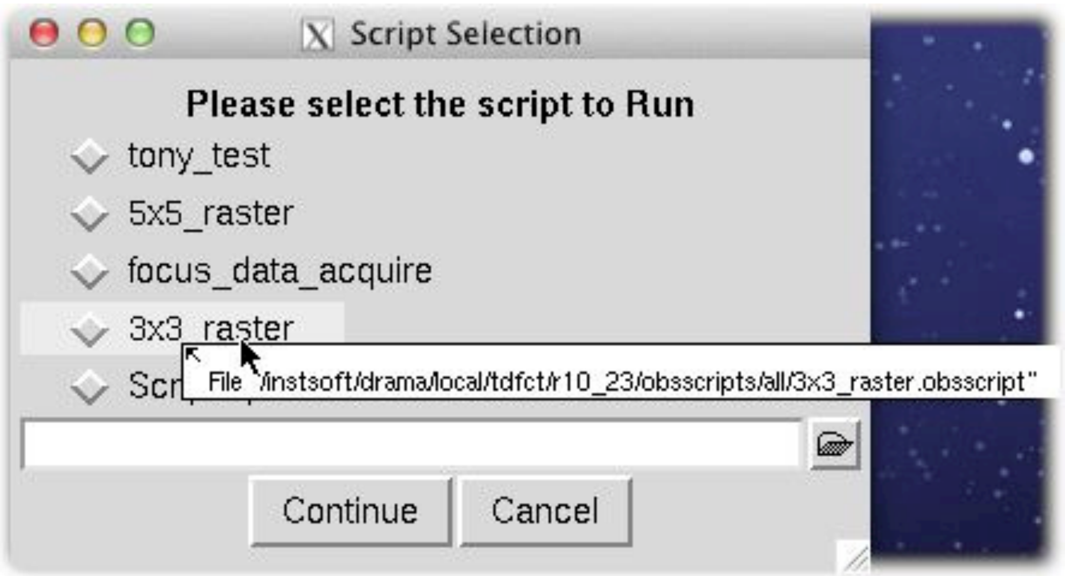


Figure 17.2: *The script file list dialog - hover the mouse over a name to see the full file name.*

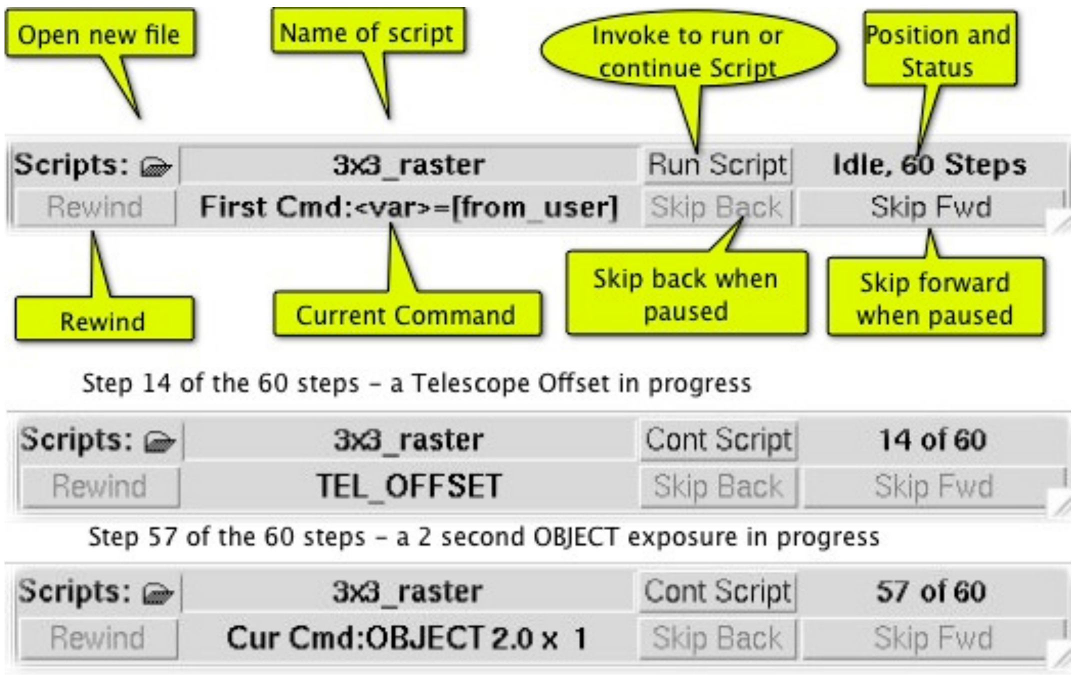


Figure 17.3: *Script control buttons and indicators. The first image is what you see on loading a script, then two examples show the status part way through a script.*

<time_spec> Is an exposure time specification. Normally a floating point exposure time in seconds. Details below.

<count> Is the number of exposures of this type to do. Defaults to 1.

<lamp_spec> Is a specification of the lamps to be turned on for <command>'s that use calibration lamps. Details below.

All commands except the BIAS command requies the exposure time to be specified.

CCD commands
The table below lists the various CCD commands and indicates if a lamp specification is required:

Command	Lamp Spec	Description
OBJECT	No	Takes a normal (on target) exposure.
BIAS	No	Takes a bias frame (shutter closed, zero second exposure). The exposure time is not required or accepted.
DARK	No	Takes a dark frame (shutter not opened).
SKY	No	Takes an offset sky exposure. The observer must arrange for the telescope to be offset to sky.
FFLAT	Flat Lamp	Takes a fibre flat field exposure.
DFLAT	Flat Lamp	Takes a detector flat field exposure. (For AAOmega, this is a defocused flat, the observer must defocus the spectrograph first and restore it afterwards (a command is available). For HERMES, this is a dithered flat)
SFLAT	No	Takes a sky flat exposure. This is normally a twilight flat. The user is responsible for acquiring twilight.
ARC	Arc Lamp	Takes an arc exposure.

Exposure time specificatons

In most cases, a single exposure time is all that is required, and you just enter a positive real number. In HERMES, it is possible to specify a different exposure time for each arm. This is done as follows

```
[ <blue_arm>, <green_arm>, <red_arm>, <infrared_arm> ]
```

Where each value (e.g. blue_arm) is an exposure time in seconds (real number). This is most likely to be required for HERMES flat fields. For example, instead of:

```
FLAT 100 [ QTZ1 ]
```

You might specify:

```
FLAT [150, 120, 100, 80] [ QTZ1 ]
```

Lamp Specifications
A lamp specification is a comma list of lamp names inclosed in "[" and "]". There are flat field lamp sets and arc lamp sets. The actual set of lamps which are available depends on the instrument in use (in particular, the focus point). The lamps sets for 2dF, Cassagrain (SPIRAL/KOALA) and prime focus (SAMI) are different. The table below lists the various specifications and indicates which are available for which instrument.

Lamp Spec	2dF	SPIRAL	KOALA	SAMI
Qtz1 (or Quartz1)	20W No.1	Chimney	TBD	Yes
Qtz2 (or Quartz2)	20W No.2	N/A	TBD	No
Qtz3 (or Quartz3)	75W (UV)	N/A	TBD	No
Qtz4 (or Quartz4)	50W No.2	N/A	TBD	No
Quartz_Def	50W No. 2	Chimney (check)	TBD	Yes (check)
ThAr1	Yes	Chimney	TBD	Yes
ThAr2	Yes	Fore-Optics	TBD	No
ThXe1	N/A	N/A	TBD	TBD
ThXe2	N/A	N/A	TBD	No
CuAr1	Yes	Chimney	TBD	No
CuAr2	Yes	Fore-Optics	TBD	No
FeAr1	Yes	Chimney	TBD	TBD
FeAr2	Yes	Fore-Optics	TBD	No
CuHe (or Helium)	Yes	Chimney	TBD	TBD
CuNe	Yes	Chimney	TBD	TBD
Focus	Yes	Yes	Yes	Yes

Below are some examples of lamp specifications:

```
[Qtz1, Qtz2]
[ThAr1, ThAr2, FeAr1, CuHe]
[Quartz_Def]
[Focus]
```

FOCUS is a special case rather then a lamp. It causes the lamps appropiate for taking spectrograph hartmann focus frames to be turned on. For AAOmega, all arc lamps except the thorium lamps are turned on. For HERMES, only the ThXe lamps are turned on. This allows the writing of spectrograph focus scripts which works with all instruments.

17.5.3 2dF Plate configuration

Commands are available to work with 2dF plate configurations. You can start plate configurations (or parking of fibres), wait for configuration to complete and tumble the field plate. The normal sequence would be to start a configuration, do other operations and then wait for your configuration to complete before tumbling.

One of the following commands can be used to start a fibre configuration:

```
CONFIGURE <file> NOTWEAK
CONFIGURE <file> TWEAK FOR PROPOSAL
CONFIGURE <file> TWEAK FOR PROPOSAL DURATION <d>
CONFIGURE <file> TWEAK FOR OFFSET <n>
CONFIGURE <file> TWEAK FOR OFFSET <n> DURATION <d>
CONFIGURE <file> TWEAK FOR TIME <abstime>
CONFIGURE <file> TWEAK FOR TIME <abstime> DURATION <d>
```

In the above, `<file>` is the name of the fibre configuration file. <d> is a real number duration in hours for the exposure, to be presumed for the tweak. If not specified, the current control task default is used. <n> is an offset in minutes from the current time to the defined middle point of the exposures on this plate (the tweak time). `<abstime>` is an absolute local time to be the tweak time.

The `PARK` command can be used to park all fibres on a plate.

The `WAIT CONFIG` command causes the script to pause until a configuration is complete. The user can abort (pause) the script during this wait if required.

The `TUMBLE` command will exchange the 2dF plates and slits in the spectrograph. If an argument is specified, it is the number of the plate to place in the configure position (0 or 1). Otherwise, the plate is tumbled to the other plate.

The file specification can be the full path name of a file, but the default of `$CONFIG_DIR/*.sds` is applied, e.g. a file type of `sds` in the directory specified by the `CONFIG_DIR` environment variable (`/instsoft/2dF`). You can also specify environment variables using the `$<varname>` format. Some configuration file name examples are

```
/instsoft/2dF/config/small_circle.sds
small_circle
small_circle.sds
$CONFIG_FILES/small_circle.sds
$CONFIG_FILES/oct13/small_circle.sds
```

Some examples of the use of these commands are given below.

```
PARK
WAIT CONFIG
TUMBLE 1
CONFIGURE configfile.sds notweak
TUMBLE
CONFIGURE configfile.sds tweak for offset 155
CONFIGURE configfile.sds tweak for PROPOSAL
CONFIGURE configfile.sds tweak for time 21:55:34
CONFIGURE configfile.sds notweak
CONFIGURE configfile.sds tweak for offset 155 duration 1.5
CONFIGURE configfile.sds tweak for PROPOSAL duration 0.5
CONFIGURE configfile.sds tweak for time 01:05:30 duration 3
```

All of the above commands are rejected if not running with 2dF.

17.5.4 SAMI plate configuration

The `CONFIGFILE` command is used to specify a SAMI plate configuration file. File name formats as per the 2dF CONFIGURE command above, except for being `.csv` files. For example.

```
CONFIGFILE samiconfigfile.csv
```

17.5.5 User Interaction from scripots

A script can interact with the user. The `WAIT` user command will create a dialog window containing its string argument and wait for the user to acknowledge it. One example of using this might be to pause a script for telescope acquisition of a field or guiding adjustments. The user can also pause the script whilst the dialog is up.

The `MSG` command is used to write a message to the control task scrolling message area. A script writer may use this to log information.

Examples of these are:

```
Wait "are we guiding now?"
Msg "Starting first set of exposures"
```

17.5.6 FITS Header items and commands

You can add FITS header items to CCD frame data files from a script. These items are recorded in all subsequent frames taken by the script, unless you explicitly clear them. Only simple real number and string items can be created.

The `FITSR` command is used to create real number items. The first argument is the header item name, the second is the value and the optional third item is the comment for the item.

The `FITSS` command is used to create string items. The first argument is the header item name, the second is the value and the optional third item is the comment for the item.

The comments are quoted strings.

The `FITSCLR` command will clear ALL items created with the above commands.

Examples of these commands are:

```
fitsclr
fitss SRASTERT "3x3" "Raster type"
fitsr SROFFSET 1 "Telescope Offset step in raster"
```

Various FITS header items are added automatically to data files when running a script.

Keyword	Description
SFILE	Written in any observation FITS file taken from a script, contains the script file name.
SLINENUM	Written in any observation FITS file taken from a scripot, contains the script file line number.
SLOFFRA	Written if the TEL_OFFSET command has been used, contains the RA offset applied.
SLOFFDEC	Written if the TEL_OFFSET command has been used, contains the Dec offset applied.

17.5.7 Other Commands

The CCD command is used to specify which CCDs are selected for the following CCD Exposure commands in the script. It takes one argument, a CCD number (1 to 2 for AAOmega, 1 to 4 for HERMES) or the token ALL to indicate all CCDs are to be selected.

The TEL_OFFSET command is used to offset the telescope. It takes two real number arguments, being the offset to apply to the telescope in arc-seconds on the tangent plane in RA and Dec. The last offset specified by this command is written to the FITS header of any data file created after this point using the SLOFFRA and SLOFFDEC keywords. These keywords can be cleared with the FITSCLR command and will be cleared when the script completes.

The SPEC_FOC_OFFSET command is used to offset the spectrograph focus (piston). It takes one or two real number arguments. If two arguments, they are offsets for each of the blue and red arms of AAOmega. If only one argument, it is used for both red and blue arms. **THIS COMMAND IS NOT YET IMPLEMENTED FOR HERMES**.

The HARTMANN command is used to control the spectrograph hartmann shutters. The single argument should be "1" or "2" to indicate the hartmann that should be closed, or "OPEN" to open both.

Some examples are given below.

```
CCD 1
CCD 2
CCD ALL
TEL_OFFSET 5.0 10.0
SPEC_FOC_OFFSET 100
SPEC_FOC_OFFSET -100 -200
HARTMANN 1
HARTMANN 2
HARTMANN OPEN
```

17.5.8 Script Variables

The scripting language implements a very simple scheme for numeric variables. Most integer or floating point values can be replaced by a reference to a variable using the format `${varname}`. Variable names are simple names, can't start with a number but can otherwise contain numbers and alphabetic characters.

Variables can be given values directly in the script using the "`name = <value>`" format. Alternatively, a script can request that the user set the value for a variable at run time, using the "`name = prompt <<usertext>>`" format, where `<<usertext>>` is some text (a quoted string) to be used in the prompt dialog. If a variable already has a value when it is prompted for, that value will be the default value for the variable and will be shown in the prompt.

The special readonly variable `${__ExpTime}` can be used to obtain the current exposure time. For example:

```
myvar1 = 10
myvar2 = 14.3
myoffset = prompt "Please enter the offset in arc seconds"
# The following grabs the current exposure time.
exptime = ${__ExpTime}
# Prompt for a new exposure time offering the current time as the default.
exptime = prompt "Please enter the exposure time in seconds"
tel_offset ${myoffset} ${myoffset}
object ${exptime}
```

Any place where you can use a variable, you can replace that by the variable multiplied by a real number. This can be useful for scripts doing rasters, for example, where you can ask the user to enter the offset basic size and then multiple it by the right units as you do your raster. E.g.

```
# Move off to the top left
tel_offset -1*${myoffset} -1*${myoffset}
object ${exptime}
# Move right by one unit to get the middle top position
tel_offset ${myoffset} 0
# Move right by one unit to get the right top position
tel_offset ${myoffset} 0
object ${exptime}
# Move down by one unit and left by two to get the left
tel_offset -2*${myoffset} ${myoffset}
```

17.6 Example Scripts

17.6.1 Instrument Focus Example

A script is used as part of a new automatic focus procedure. Its job is to collect the data required, operating the hartmann shutters as needed. Below is the script used by the Automatic Focus procedure.

```
#  focus.obsscript
#
# Description:
#     This script takes the required set of  focus observations.
#
#     The user is prompted for the exposure time.
#     The Hartmann 1 shutter is closed
#      An arc exposure is taken with the appropiate lamps on. (depends on instrument mode)
#     The Hartmann 2 shutter is closed (1 is opened).
#      An arc exposure is taken with the appropiate lamps on. (depends on instrument mode)
#     The Hartmann shutters are opened.
#
#    It will prompt for the exposure time
#
#
# FITS Keywords set by scripting system when running this script"
#    SFILE       -> Script file name
#    SLINENUM    -> Line in script which took observation.
#
wait "This script will take the observations required to focus the spectrograph"
# Default exposure time is current exposure time.
exptime = ${__ExpTime}
exptime = prompt "AAOmega Focus:Please enter the exposure time in seconds"
hartmann 1
arc ${exptime} [Focus]
hartmann 2
arc ${exptime} [Focus]
hartmann open
```

17.6.2 Raster Example

Below is a complete documented example for implementation of a 3x3 raster. This script prompts the user for the exposure time for each observation done and the size of the offset.

```
#  3x3_raster.obsscript
#
# Description:
#     This script implements a 3x3 raster
#
#    22 exposures are done, start point, 3x3 and again at the start point
#
#    It will prompt for the exposure time
#    It will prompt for the size of the offset
#
# FITS Keywords set by script:
#    SRASTERT   -> Raster type, set to 3x3
#    SROFFSET   -> Telescope offset used in raster
#    SRRAOFF    -> Offset of telescope from raster start position, RA.
#    SRDECOFF   -> Offset of telescope from raster start position, DEC.
#    SRASTERN   -> File number raster in sequence.
#
# FITS Keywords set by scripting system when running this script"
#    SFILE       -> Script file name
#    SLINENUM    -> Line in script which took observation.
#    SLOFFRA     -> Last telescope offset done in script - Dec.
#    SLOFFDEC    -> Last telescope offset done in script - RA.
#                    SLOFFRA/SLOFFDEC are not set for the first exposure.
#
#

myoffset = prompt "3x3 Raster:Please enter the offset in arc seconds"
exptime = prompt "3x3 Raster:Please enter the exposure time in seconds"

fitss SRASTERT "3x3" "Raster type"
fitsr SROFFSET ${myoffset} "Telescope Offset step in raster"

# Grab an image at the centre.
fitsr SRRAOFF 0 "Telescope Offset from raster start point, RA"
fitsr SRDECOFF 0 "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 1 "Image number in raster - 1 to 11"
object ${exptime}

# # # # # #
#
# We are going to do three lines.  Move off to the top left
#
tel_offset -1*${myoffset} -1*${myoffset}

fitsr SRRAOFF -1*${myoffset} "Telescope Offset from raster start point, RA"
fitsr SRDECOFF -1*${myoffset} "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 2 "Image number in raster - 1 to 11"
object ${exptime}

# Move right by one unit to get the middle top position
tel_offset ${myoffset} 0

fitsr SRRAOFF 0 "Telescope Offset from raster start point, RA"
fitsr SRDECOFF -1*${myoffset} "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 3 "Image number in raster - 1 to 11"
object ${exptime}

# Move right by one unit to get the right top position
tel_offset ${myoffset} 0

fitsr SRRAOFF ${myoffset} "Telescope Offset from raster start point, RA"
fitsr SRDECOFF -1*${myoffset} "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 4 "Image number in raster - 1 to 11"
object ${exptime}

# # # # # #
```

```
# Move down by one unit and left by two to get the left
tel_offset -2*${myoffset} ${myoffset}

fitsr SRRAOFF -1*${myoffset} "Telescope Offset from raster start point, RA"
fitsr SRDECOFF 0 "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 5 "Image number in raster - 1 to 11"
object ${exptime}


# Move right by one unit, should be back in the centre
tel_offset 1*${myoffset} 0
fitsr SRRAOFF  0 "Telescope Offset from raster start point, RA"
fitsr SRDECOFF 0 "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 6 "Image number in raster - 1 to 11"
object ${exptime}



# Move right by one unit, to get the right
tel_offset ${myoffset} 0
fitsr SRRAOFF  0 "Telescope Offset from raster start point, RA"
fitsr SRDECOFF 0 "Telescope Offset from raster start point, Dec"

fitsr SRRAOFF  ${myoffset} "Telescope Offset from raster start point, RA"
fitsr SRDECOFF 0 "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 7 "Image number in raster - 1 to 11"
object ${exptime}

# # # # # #
# Move down by one unit and left by two to get the bottom left
tel_offset -2*${myoffset} ${myoffset}

fitsr SRRAOFF -1*${myoffset} "Telescope Offset from raster start point, RA"
fitsr SRDECOFF ${myoffset} "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 8 "Image number in raster - 1 to 11"
object ${exptime}

# Move right by one unit to get the bottom middle position
tel_offset ${myoffset} 0

fitsr SRRAOFF  0 "Telescope Offset from raster start point, RA"
fitsr SRDECOFF ${myoffset} "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 9 "Image number in raster - 1 to 11"
object ${exptime}

# Move right by one unit to get the bottom right
tel_offset ${myoffset} 0

fitsr SRRAOFF  ${myoffset} "Telescope Offset from raster start point, RA"
fitsr SRDECOFF ${myoffset} "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 10 "Image number in raster - 1 to 11"
object ${exptime}

# # # # # #
# Move back to the centre
tel_offset -1*${myoffset}  -1*${myoffset}

fitsr SRRAOFF  0 "Telescope Offset from raster start point, RA"
fitsr SRDECOFF 0 "Telescope Offset from raster start point, Dec"
fitsr SRASTERN 11 "Image number in raster - 1 to 11"
object ${exptime}
```

Chapter 18

Working with Complex configurations

This section covers more detailed information, and many users can safely skip it.

Recent years have seen a rise in the number of programs that require complex configuration strategies to maximize the yield of an AAOmega observing run. This guide is intended to outline some of the strategies that have been adopted in the past. It is not exhaustive, and we welcome comments and suggestions.

Large scale survey programs have their own special requirements with regard to target allocation priorities. The GAMA survey project (Driver et al. 2009 A&G 50 12) implemented a very detailed, multi-year, survey strategy which is documented in Robotham et al. 2010 PASA 27 76. While this strategy is likely more complex than most program will need, many of the issues of concern are discussed.

This guide is not intended to replace the Configure manual

18.1 The need for complex configurations

AAOmega has only ~350-400 fibres once sky fibres and the current status of fibres is taken into account. Therefore the ideal AAOmega program has of the order of 400 targets per 2degree diameter field and a uniform target distribution with no closely spaced targets. Unfortunately, nature does not work like that. This results in extended target lists, with multiple priority levels and strongly clustered source distributions. The Configure software is necessarily generic, requiring the observer to carefully define input target lists.

The main points to consider are:

- Number of targets. In most cases, and particularly so for the default Simulated Annealing Configure algorithm, simply passing a list of >1,500 targets to Configure will not produce optimal results. With around 350-400 fibres available per configuration, target lists should normally be re-sampled to include only a small excess of targets to fibres in the input file. 800-1000 targets works well for relatively uniform fields, lower numbers are needed for more compact fields.

- Repeat observations. In surveys where the same (or overlapping) fields will be targeted multiple times, it is often advantageous to reallocate targets between observations. This can increase the total target yield by rejecting targets that are confirm to have unwanted spectral types, or replacing objects for which the spectral quality obtained is already sufficient.

- Locking a sub-set of allocations. You may wish to force the repeat observation of a sub-set of high priority targets, at the expense of a large number of lower ones, but also include these lower priority targets in a new configuration where possible. There is a facility to lock fibres in place between configurations.

A simple way to cover multiple targets in a field, using repeat observations, is outlined in section 5.4 of the configure manual "Multiple configurations to cover a target list". The process uses the option to save the unallocated targets from a configuration to a file, using the menu option File->list... in Configure. While this technique certainly works, and is discussed below, it is limited in that it can be rather tedious to undertake, and also cannot be done efficiently in advance of a run, since the 2dF astrometric solution will change before the run and so many allocations will not be valid during the obseravtions. A better solution is outlined in Example 2 below.

18.1.1 Examples

Example 1 - Simple multiple configurations

Starting from a large master catalogue:

1. Allocate the field using configure
2. Save the .sds file.
3. Also save a .lis file (File->List...) which contains the unallocated objects (this is an option in the pop-up that will appear then you select File->List...). The .lis file format for the unallocated objects is the same as that for an input .fld file. If you select one of the other save options, the formatting will be a little different.
4. Load this .lis file into configure and rerun the configuration, saving a new .lis file of the outstanding unallocated objects each time.

Example 2 - Configuration using a master catalogue, and current status list

For the reasons below, Example 1 above is not the preferred approach for most programs:

1. For the first run in any AAOmega observing block, the astrometric files will not be available prior to the run, and hence the configurations would be invalid if prepared in advance. This is typically only a small effect, but is compounded with each new iteration.
2. The fibre availability of the field plates will change with time during a run, due to the slow rate of fibre attrition.
3. No accounting is made for data quality once observations have begun.
4. There is little flexibility between the interchange of the two 2dF field plates during observations.

The solution is to prepare a master catalogue, with target observation priorities, for your full observing region and to create a processing script to draws sources from this catalogue based on external constraints. For example:

1. Choose the first pointing centre for observation.

2. Make a .fld file, select 500-800 high priority targets from the master catalogue. The UNIX grep and awk commands are ideal here, or a simple Perl script may be the best way to achieve this goal.

3. If there are a small number of high priority targets, pad out the .fld file with lower priority objects. Care should be taken if a large number of low priority targets are introduced. The user should examine the configuration at step 5 below, to ensure a sensible fibre distribution is being used.

4. Insert ˜30-50 guide stars and ˜50-100 blank sky positions.

5. Configure and inspect the configuration

6. Observe the field.

7. Examine the spectra (determine redshifts, measure radial velocities, classify objects etc.)

8. Update the master catalogue to reflect these observations. A safer approach is often to create a second catalogue of new target priorities. The processing script would then draw targets for subsequent configurations from the master file, but the priorities of classified targets are adjusted based on the information you have entered into the new target priorities catalogue. For example: Set the priority of objects with satisfactory spectra to the lowest value (Pri=1); Remove objects of the wrong spectral type; Flag objects with promising spectra, but which will need higher signal-to-noise. Note, you clearly cannot make the new target priorities until you have some data, and since one needs to have a number of .fld files ready in advance of each nights observing, this process is most efficient if any given region can be broken down into a number of independent (non-overlapping) pointing centres each night.

9. Note, that there is no underlying reason why the field centre need be identical to that previously used.

10. Repeat steps 5-9 until the required target completeness is achieved.

18.2 Locking allocations for repeat observing

NOTE:
In the discussion that follows, it is assumed that you are trying to lock the allocation to the same field plate for which it was originally configured, and that you are observing at a similar Hour Angle (HA). Trying to lock the fibres to the same targets on different field plates or for a very different HA may fail to configure due to fibre collisions.

It can often be useful to lock a number of fibres (any number between 1 and 399) onto certain targets while still allowing Configure to freely allocate the rest of the fibres. The classic example is that a field has been observed for 2 hours on one night and it has returned redshifts for half of the targets but the remaining targets need to be observed for a second 2 hours, as per the original telescope proposal, while adding in additional targets for the remaining fibres.

It is possible to force the allocation of some fibres on to previously observed targets, and then reconfigure the remaining objects.

18.2.1 The procedure for creating and using an import file

1. Load your .fld file as normal, and configure as normal.
2. Save the .sds file.
3. Save a .lis file using the File->List.. menu option.
4. Edit the list file to create a new file, by default Configure is expecting a .imp file. The nature of the Edit is discussed below.
5. Reopen your .fld file (NOT your .sds file).
6. Turn on Expert mode in Configure (select the Expert flag in the Options menu).
7. From the Commands menu, select Import Allocations... and select your .imp file. This will allocate the fibres as specified in the .imp file.
8. Now select Lock Allocations.
9. You can now proceed with the normal configuration, as you did in step 1 above, but the locked fibres will stay in place.

18.2.2 Creating your .imp file

The file saved by the File->List option in Configure, a .lis file by default, is a plain text file which shows which fibres are allocated to which targets. The format is close to that of a .fld file, but with an additional column of * and a column of Fibre numbers between the * and the Object Names.

The .imp file format is almost identical to that of a standard .fld file, but with the addition of an extra column of fibre numbers. This column should be the very first column, i.e. it goes **before** the Object Name column of a standard .fld file.

To convert the .lis file into a .imp file, simply delete the first column of * characters that have been added.

Modify the contents of the .imp file to only list those fibres needing to be locked, or else all 400 fibres will stay locked. For some programs it may be possible to edit the .imp file by hand in a text editor. For most programs, you will probably want to write a simple script to remove or re-prioritize allocations based on the results of an initial examination of the spectra from a first observation.

18.3 AAOmega: set_fibre_state tool

From time to time, it can be desirable to temporarily deactivate specific fibres for the 2dF positioner. The most common reason for this is to set up a field for Nod and Shuffle observations where a number of fibres need to be disabled in addition to those that are un-available due to damage. The temporary removal of fibres with poor characteristics (e.g. fringing fibres is also possible.

To facilitate the temporary disabling of fibres a utility program has been packaged with Configure from v7.7 onwards.

The routine set_fibre_state can be found in the base directory of the Configure distribution. The utility should be set to be locally executable. Running the script will then provide an introduction to its usage. Under LINUX this looks like:

```
LINUX> chmod +x set_fibre_state
LINUX> ./set_fibre_state
    Insufficient arguments.
    2dF set fibre state program - Usage:
     ./set_fibre_state <tdFconstants400.sds> shuf  0|1|both
     ./set_fibre_state <tdFconstants400.sds> file  0|1      <file>
     ./set_fibre_state <tdFconstants400.sds> file  both     <file1> [<file2>]
     ./set_fibre_state <tdFconstants400.sds> restore<file>
```

In the syntax above the arguments in <> are user supplied input files.

There are three basic modes of operation, shuffle, file (with two syntax options) and restore. Shuffle will create a new file for tdFconstants400.sds file with the fibres on one or both plates correctly disabled for nod-and-shuffle observing whereas the file option allows the user to selectively disable fibres.

In all modes of operations, the script should be run on the tdFconstants400.sds file found in the /path/configure-V.V/data_files/ directory. Doing this away from the telescope requires installing the latest tdFconstants400.sds file. The current tdFconstants400.sds file can be found through the main configure page. The code will create a back up of the old constants file, tdFconstants400.sds.bck, and a restore file tdFconstants_changes.txt which can be used with the restore option to reverse the changes made to the tdFconstants400.sds file.

Note for configure-7.9-1 onwards: The mapping of fibres in 2dF is not always 1-to-1 with the fibre slit position. From v7.9.1 onwards, set_fibre_state requires access to the spec_fibres.txt file, which is available from the support astronomer, in order to achieve this mapping. The fibre ordering is currently a 1-to-1 mapping.

18.3.1 Nod and Shuffle mode

Nod and Shuffle mode creates a tdFconstants400.sds file with every alternate AAOmega fibre (at the AAOmega slit end NOT at the positioner end) disabled so as to be masked off during Nod and Shuffle observations. By default, the script disables even numbered fibres, since the 8 AAOmega guide fibres are even numbers (50, 100, ... 350, 400) and are already disabled on the CCD (by virtue of not being in the slit unit). They are left active so as to be positionable by 2dF on the field plate.

Run the script with:

./set_fibre_state tdFconstants400.sds shuf 0—1—both shuf

The 0—1—both option allows the user to make the relevant changes to only one plate or to both plates. For N+S, the both option is typically required.

18.3.2 File mode

The File mode option allows the user to make an ascii file which lists the 2dF positioner pivot number for one or both 2dF field plates, and then disables the listed fibres. The text file format is a simple list of integers, one integer per line, with lines beginning with # considered comments and hence ignored. An individual field plate can be modified with:

./set_fibre_state tdFconstants400.sds file 0 text.file0

or

./set_fibre_state tdFconstants400.sds file 1 text.file1

Or both plates can be modified at once using the format:

./set_fibre_state tdFconstants400.sds file both text.file0 text.file1

18.3.3 Restore mode

The restore option uses the tdFconstants_changes.txt created by the set_fibre_state to reverse the changes to the setup file. The syntax follows:

./set_fibre_state tdFconstants400.sds restore tdFconstants_changes.txt

Note, this will reverse the last set of changes made to the tdFconstants400.sds file. If multiple changes have been made, while experimenting with the script, it is probably safer to simply overwrite the tdFconstants400.sds with a private back up (note, multiple changes to the file may mean that the task's own backup file, tdFconstants400.sds.bck, is not actually what the user wants. A private back up is invaluable here).