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The ECH Echelle Spectrograph Model Package

Contents

1 Introduction

The ECH package consists of a set of routines which model the behaviour of the UCL coudé echelle spectrograph (UCLES) and of echelle spectrographs of similar design. Such spectrographs can differ in

- collimator focal length (which is in fact irrelevant to the model package)
- cross dispersing prism apex angle
- echelle ruling frequency
- echelle blaze angle
- camera focal length

It is not capable of dealing with spectrographs which differ in any more major ways from UCLES, although it could be extended to do so should the need arise.

2 Routine Summary

The following routines are available. Refer to the next section for an overview of how they are used.

`ECH_BLOCK`: `BLOCK DATA` to initialise spectrograph configuration `COMMON` block

`ECH_COLLIMATOR`: Determine which collimator to use at a given wavelength

`ECH_DISP`: Determine the dispersion in mm for a given wavelength in a given order at a specified configuration

`ECH_FORMAT_CENTRE`: Determine the appropriate spectrograph settings to place a specified wavelength in a specified order at the centre of the field

`ECH_FRSPR`: Determine the free spectral range in Angstroms of a specified order at a specified configuration

`ECH_INIT`: Initialise `COMMON` blocks for a specified instrument combination

`ECH_LOAD`: Load `COMMON` blocks describing spectrograph parameters

`ECH_ORDERNUM`: Determine the order number of a specified wavelength at a specified configuration

`ECH_PRISMPOS`: Determine the optimal prism rotation and position at a specified wavelength

`ECH_REFINDEX`: Determine the refractive index of fused silica at a specified wavelength

`ECH_SLITANGLE`: Determine the optimum slit angle at a specified configuration

`ECH_WAVECEN`: Determine the central wavelength of the order nearest to the centre of the field at a specified configuration

`ECH_WCENTRAL`: Determine the central wavelength in Angstroms in a specified order at a given configuration

`ECH_XDISPFS`: Determine the cross-dispersion in mm for a given wavelength at a specified configuration

3 Overview

The routine that is called is `ECH_LOAD`. This reads and interprets a spectrograph parameter file which defines the list of available spectrographs and their echelles and cameras. The use of `ECH_LOAD` is in fact optional — if it is not called then only UCLES with its 31 and 79 echelle and its long camera is available.

The next routine that is called is `ECH_INIT`. This selects the actual instrument / echelle / camera combination that is to be modelled. `ECH_INIT` allows use of the syntax "instrument/echelle/camera" in response to the prompt for the echelle name. The user response is split up into tokens and then the first token is checked against the list of defined instruments. If it matches one of them, attention switches to the next token. If it doesn't, the first instrument defined in the spectrograph parameter file is assumed and the same token is regarded as a candidate echelle name. The list of defined echelles for the current instrument is searched in exactly the same way, as is the list of defined cameras. Attention only moves to the next token if a match is found to the current token. If, after all this, any unmatched tokens remain, an error is reported and the first instrument / echelle / camera combination defined in the spectrograph parameter file is assumed.

Once `ECH_INIT` has been called, any of the other routines can be called. Two of the routines are at a higher level than the rest of them. These are `ECH_FORMAT_CENTRE`, which determines the spectrograph settings for a given central wavelength and order number, and `ECH_WAVECEN`, which determines the central wavelength and order number for a given set of spectrograph settings.

One of the best ways to work out how to use the routines is to study and understand examples of their use. The source code for the ECHWIND program is a good place to start and Francisco Diego's PhD thesis (he is one of the principal designers of UCLES) provides much valuable background information and develops most of the algorithms. A future version of this note will perhaps contain more examples.

A Routine Descriptions

This section contains details of each routine. In particular, refer to the descriptions of the `ECH_LOAD` and `ECH_INIT` routines for details of how to create and use spectrograph parameter files, and refer to the description of the `ECH_FORMAT_CENTRE` routine for details of how the spectrograph configuration for a specified wavelength is determined.

ECH_BLOCK
BLOCK DATA to initialise spectrograph configuration

Description

This refers to the ECH_PARAMS COMMON block, which contains the parameters of all possible spectrographs, not to the ECH_COMMON COMMON block, which contains the details only of the current configuration.

This BLOCK DATA initialises the COMMON block in such a way that a call to ECH_INIT without a call to ECH_LOAD to load the parameters of a specific spectrograph configuration will use the values which are correct for UCLES. These values also serve to provide defaults for quantities which are not overridden as a result of ECH_LOAD.

Bugs

None known.

Authors

W.F. Lupton AAO (AAOEPP::WFL)

ECH_COLLIMATOR
Determine which collimator to use at a given wavelength

Description

If a central wavelength is given, use the WIDE collimator for wavelengths longer than 4000 Angstroms and the UV collimator otherwise. Otherwise make the decision based on whether gamma is greater or less than 0.1369 degrees. For UCLES, this value of gamma corresponds a central wavelength of very close to 4000 Angstroms.

Invocation

CALL ECH_COLLIMATOR (WAVE, GAMMA,COLOUR, STATUS)

Arguments

READ	WAVE	REAL	Central wavelength of detector. If specified as <= 0, is not used (Angstroms)
READ	GAMMA	REAL	Echelle gamma angle corresponding to the current configuration. Is used only if WAVE is <= 0 (radians)
WRITE	COLOUR	CHARACTER	The optimal collimator, either WIDE or UV
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

The algorithm is too simplistic. It should take account of the detector size and guarantee that the best choice of collimator is made for the whole detector rather than just for its centre (although this is rather hard without knowledge of the configuration history!).

Authors

C.J. Hirst UCL (ZUVAD::CJH)

ECH_DISP
Determine the dispersion in mm for a given wavelength

Description

Use the grating equation to calculate the echelle beta angle at the given wavelength in the given order. Then calculate it at the point where the dispersion is by definition zero. Knowing the focal length of the camera, calculate the dispersion in mm.

ECH_INIT must be called before calling this routine.

Invocation

CALL ECH_DISP (WAVE, M, THETA, GAMMA, DEL, STATUS)

Arguments

READ	WAVE	REAL	Wavelength of point at which dispersion is to be calculated (Angstroms)
READ	M	INTEGER	Order number in which this wavelength lies (it doesn't have to be within the free spectral range)
READ	THETA	REAL	Echelle theta angle corresponding to the current configuration (radians)
READ	GAMMA	REAL	Echelle gamma angle corresponding to the current configuration (radians)
WRITE	DEL	REAL	Dispersion (mm)
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

C.J. Hirst UCL (ZUVAD::CJH)

ECH_FORMAT_CENTRE
Determine the appropriate spectrograph settings

Description

Firstly, calculate the prism system rotation and position. The required echelle gamma angle is not quite the same as the prism rotation angle. This is because of the 12 degree separation between the incoming ray to to the echelle grating and the outgoing ray to the camera - the prism rotation angle has to be multiplied by an empirical correction factor of 1.011 (I am not sure of the complete justification for this).

Having determined the appropriate echelle gamma angle, the cross dispersion is now correct and it is necessary to determine the appropriate echelle theta angle to give the correct wavelength in the centre of the field. If the order number was not explicitly specified, assume the order within which the given wavelength lies with the free spectral range. Theta is determined simply by stepping along the order and, once having stepped past the required wavelength, binary chopping until convergence.

Finally, determine the appropriate collimator to use and the necessary slit assembly rotation in order to give vertical slit images on the detector.

ECH_INIT must be called before calling this routine.

Invocation

CALL ECH_FORMAT_CENTRE (WC, MCEN, THETA, GAMMA, COL_COLOUR, PRISM_POS, SLIT_ANGLE, STATUS)

Arguments

READ	WC	REAL	Desired central wavelength (Angstroms)
READ	MCEN	INTEGER	Desired central order. If <=0 the order in which the above wavelength lies within the free spectral range is used
WRITE	THETA	REAL	Echelle theta (radians)
WRITE	GAMMA	REAL	Echelle gamma (radians)
WRITE	COL_COLOUR	CHARACTER	Collimator (UV or WIDE)
WRITE	PRISM_POS	REAL	Prism position (mm)
WRITE	SLIT_ANGLE	REAL	Slit angle (radians)
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

F. Diego UCL (ZUVAD::FD)

ECH_FRSPR
Determine the free spectral range in Angstroms

Description

Determine the central wavelength of the specified order and then use the grating equation directly to calculate the free spectral range.

ECH_INIT must be called before calling this routine.

Invocation

CALL ECH_FRSPR (M, THETA, GAMMA, FREE, STATUS)

Arguments

READ	M	INTEGER	Order number for which to calculate the free spectral range
READ	THETA	REAL	Echelle theta angle corresponding to the current configuration (radians)
READ	GAMMA	REAL	Echelle gamma angle corresponding to the current configuration (radians)
WRITE	FREE	REAL	Free spectral range (Angstroms)
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

C.J. Hirst UCL (ZUVAD::CJH)

ECH_INIT
Initialise COMMON blocks for a specified instrument combination

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Description

If a parameter name has been specified, ask the user which configuration to use. Otherwise use the one which was supplied.

The resulting configuration name is a string which consists of zero or more words separated by slahes. They are converted to upper case and then an attempt is made to interpret the first as the name of a supported instrument. If no match is found, the first instrument defined in the spectrograph parameter file read by ECH_LOAD is assumed or, if ECH_LOAD was not called, the default instrument (UCLES) is used. Having determined the instrument, an attempt is made to interpret the remaining words as names of supported echelles and cameras respectively. If no match is found, the first defined echelle and camera of the instrument are assumed.

Having determined the instrument, echelle and camera, copy the relevant parameters to the ECH_COMMON COMMON block for use by the rest of the spectrograph model routines.

The result is that simple input such as "31" and "79" can continue to be accepted as it always has, but that it is easy to refer to other instruments, echelles and cameras.

This routine must be called before any of the other spectrograph model routines are called. ECH_LOAD may optionally be called before this routine. If it is not, the only available instrument is UCLES with the 31 and 79 echelles and the LONG camera.

Invocation

CALL ECH_INIT (PARAM, CONFIG, STATUS)

Arguments

READ	PARAM	CHARACTER	Name of program parameter corresponding to the configuration to use. If blank, no parameter is read
READ, WRITE	CONFIG	CHARACTER	Configuration to use. See description above. Is read if PARAM is blank. Is set to echelle name if PARAM is non-blank
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

C.J. Hirst UCL (ZUVAD::CJH)

ECH_LOAD
Load COMMON blocks describing spectrograph parameters

Description

If a parameter name has been specified, ask the user which file contains the parameters. Otherwise use the one which was supplied.

This file is a text file. Any line beginning with a "!" is a comment line and is ignored. Non-comment lines are split up into space, tab or comma separated tokens (quotes can be used to protect delimiters within tokens should this be necessary) and these tokens are processed in pairs (the number of tokens on a line must be even and will probably usually be 2). The first of each pair is a keyword and the second is a value associated with that keyword. The keyword determines the expected type of the value. All non quoted tokens are converted to upper case.

As the file is processed, there is always a current instrument, a current echelle and a current camera. Initially these are the defaults of "UCLES", "31" and "LONG" respectively. They are changed by "INSTRUMENT instrument", "ECHELLE echelle" and "CAMERA camera" entries in the file. Individual spectrograph parameters are each associated with the instrument and with either

the echelle or the camera and their entries always apply to the current instrument, echelle and camera.

Instrument-related parameters are:

FCOL collimator focal length (`REAL` mm)

NPR number of prisms in cross-disperser (`INTEGER`)

ANGLE prism angle (`REAL` degrees)

Echelle-related parameters are:

D number of lines per mm (`REAL`)

M0 central order number (`INTEGER`)

WAVE0 central wavelength (`REAL` Angstroms)

THETAB blaze angle (`REAL` degrees)

THETA0 central theta (`REAL` degrees)

GAMMA0 central gamma (`REAL` degrees)

Camera-related parameters are:

FCAM camera focal length (`REAL` mm)

Note that the order of instruments, echelles and cameras within the file may be significant. For example, the default instrument, echelle or camera may be the first one that was defined in the file (although this routine does not need to make any assumptions about this).

The following example describes `UCLES` and illustrates a notional short camera of focal length 400mm.

```
*       !+ UCLES.DAT
*       !
*       !  UCLES spectrograph parameters.
*       !
*       INSTRUMENT UCLES
*          FCOL 6000.0
*          NPR 3
*          ANGLE 54.1
*          ECHELLE 31
*             D 31.6046
*             M0 138
*             WAVE0 4119.68
*             THETAB 64.66
*             THETA0 0.0
*             GAMMA0 0.0
*          ECHELLE 79
```

```
*             D 79.0115
*             MO 55
*             WAVE0 4097.99
*             THETAB 63.55
*             THETA0 0.0
*             GAMMA0 0.0
*          CAMERA LONG
*             FCAM 700.0
*          CAMERA SHORT
*             FCAM 400.0
```

This routine should be called before ECH_INIT is called. If it is not called, ECH_INIT will only be able to support the 31 and 79 echelles on the UCLES LONG camera.

Invocation

CALL ECH_LOAD (PARAM, FILE, STATUS)

Arguments

READ	PARAM	CHARACTER	Name of program parameter corresponding to the file to use. If blank, no parameter is read
READ, WRITE	FILE	CHARACTER	File to use. Default file type is .DAT. Is read if PARAM is blank. Is written if PARAM is non-blank
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

W.F. Lupton AAO (AAOEPP::WFL)

ECH_ORDERNUM
Determine the order number of a specified wavelength

Description

Use the grating equation to calculate the free spectral range and then derive the order number directly from it.

ECH_INIT must be called before calling this routine.

Invocation

CALL ECH_ORDERNUM (W, THETA, GAMMA, M, STATUS)

Arguments

READ	W	REAL	Wavelength whose order number is to be determined (ie the order number within which it lies within the free spectral range) (Angstroms)
READ	THETA	REAL	Echelle theta angle corresponding to the current configuration (radians)
READ	GAMMA	REAL	Echelle gamma angle corresponding to the current configuration (radians)
WRITE	M	INTEGER	Order number corresponding to wavelength
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

C.J. Hirst UCL (ZUVAD::CJH)

ECH_PRISMPOS
Determine the optimal prism rotation and position

Description

Determine the prism rotation and position by direct calculation. The rotation is such that a ray of the specified wavelength will fall on the centre of the detector. The position is such that the echelle is fully illuminated by rays of the specified wavelength.

ECH_INIT must be called before calling this routine.

Invocation

CALL ECH_PRISMPOS (WC, GAMMA, POS, STATUS)

Arguments

READ	WC	REAL	Desired central wavelength (Angstroms)
WRITE	GAMMA	REAL	Optimal prism rotation (radians)
WRITE	POS	REAL	Optimal prism position (mm)
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

C.J. Hirst UCL (ZUVAD::CJH)

ECH_REFINDEX
Determine the refractive index of fused silica

Description

Use the empirical expression derived by I.H. Malitson, J.O.S.A 55, 1205, Oct 1965. This expression is:

```
*                  0.6961663 . w**2     0.4079426 . w**2      0.8974794 . w**2
*     ref**2 = 1 + ----------------- + -------------------- + -------------------
*                 w**2 - 0.0684043**2  w**2 - 0.0062414**2   w**2 - 9.896161**2
```

where wavelength is measured in microns. This routine uses wavelength in Angstroms and converts to microns internally.

Invocation

CALL ECH_REFINDEX (WAVE, REF, STATUS)

Arguments

READ	WAVE	REAL	Wavelength (Angstroms)
WRITE	REF	REAL	Refractive index
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

W.F. Lupton AAO (AAOEPP::WFL)

ECH_SLITANGLE
Determine the optimum slit angle

Description

Determine the slit angle by direct calculation.

ECH_INIT must be called before calling this routine.

Invocation

CALL ECH_SLITANGLE (GAMMA, ANG, STATUS)

Arguments

READ	GAMMA	REAL	Echelle gamma angle corresponding to the current configuration (radians)
WRITE	ANG	REAL	Optimal slit angle (radians)
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

C.J. Hirst UCL (ZUVAD::CJH)

ECH_WAVECEN
Determine the central wavelength of the order

Description

Use a binary chop search to determine the order which corresponds to the given echelle gamma angle. Having determined the order, perform a similar search to determine the wavelength within the order which corresponds to the given echelle theta angle.

ECH_INIT must be called before calling this routine.

Invocation

CALL ECH_WAVECEN (THETA, GAMMA, WC, MC, STATUS)

Arguments

READ	THETA	REAL	Echelle theta angle corresponding to the current configuration (radians)
READ	GAMMA	REAL	Echelle gamma angle corresponding to the current configuration (radians)
WRITE	WC	REAL	Central wavelength corresponding to the current configuration (ie that wavelength which lies within order M and is closest to that in the centre of the field)
WRITE	MC	INTEGER	Order number corresponding to the current configuration (the order closest to that in the centre of the field)
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

C.J. Hirst UCL (ZUVAD::CJH)

ECH_WCENTRAL
Determine the central wavelength in Angstroms

Description

Use the grating equiation directly to determine the central wavelength.

ECH_INIT must be called before calling this routine.

Invocation

CALL ECH_WCENTRAL (M, THETA, GAMMA, WC, STATUS)

Arguments

READ	M	INTEGER	Order number
READ	THETA	REAL	Echelle theta angle corresponding to the current configuration (radians)
READ	GAMMA	REAL	Echelle gamma angle corresponding to the current configuration (radians)
WRITE	WC	REAL	Central wavelength of this order (Angstroms)
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

C.J. Hirst UCL (ZUVAD::CJH)

ECH_XDISPFS
Determine the cross-dispersion in mm for a given wavelength

Description

Calculate the refractive index at the given wavelength. Then calculate it at the point where the cross-dispersion is by definition zero. Knowing the focal length of the camera, calculate the

cross-dispersion in mm on the assumption that the light enters and leaves the prisms at the same angles of incidence (a first order approximation is used).

ECH_INIT must be called before calling this routine.

Invocation

CALL ECH_XDISPFS (WAVE, GAMMA, DEL, STATUS)

Arguments

READ	WAVE	REAL	Wavelength of point at which cross-dispersion is to be calculated (Angstroms)
READ	GAMMA	REAL	Echelle gamma angle corresponding to the current configuration (radians)
WRITE	DEL	REAL	Cross-dispersion (mm)
READ, WRITE	STATUS	INTEGER	Global status value

Bugs

None known.

Authors

C.J. Hirst UCL (ZUVAD::CJH)