Guide to the Coude Three Fiber Reduction Task DO3FIBER

Francisco Valdes

IRAF Group - Central Computer Services
National Optical Astronomy Observatories††
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ABSTRACT

The **do3fiber** reduction task is specialized for the extraction, flat fielding, and wavelength calibration of multifiber data in which some fibers are used to take object spectra and other fibers are used to take simultaneous arc spectra. A three fiber instrument of this type (one object and two arc fibers) is available at the KPNO coude feed. The default parameters are set for this configuration. If there are a large number of fibers and fiber throughput and sky fiber subtraction is needed the **dofiber** task should be used.

The **do3fiber** task is a command language script which collects and combines the functions and parameters of many general purpose tasks to provide a single complete data reduction path. The task provides a degree of guidance, automation, and record keeping necessary when dealing with this type of multifiber data.

1. Introduction

The **do3fiber** reduction task is specialized for the extraction, flat fielding, and wavelength calibration of multifiber data in which some fibers are used to take object spectra and other fibers are used to take simultaneous arc spectra. A three fiber instrument of this type (one object and two arc fibers) is available at the KPNO coude feed. The default parameters are set for this configuration. If there are a large number of fibers and fiber throughput and sky fiber subtraction is needed the **dofiber** task should be used.

The **do3fiber** task is a command language script which collects and combines the functions and parameters of many general purpose tasks to provide a single complete data reduction path. The task provides a degree of guidance, automation, and record keeping necessary when dealing with this type of multifiber data.

The general organization of the task is to do the interactive setup steps first using representative calibration data and then perform the majority of the reductions automatically, and possibly as a background process, with reference to the setup data. In addition, the task determines which setup and processing operations have been completed in previous executions of the task and, contingent on the `redo` and `update` options, skip or repeat some or all the steps.

The description is divided into a quick usage outline followed by details of the parameters and algorithms. The usage outline is provided as a checklist and a refresher for those familiar with this task and the component tasks. It presents only the default or recommended usage. Since **do3fiber** combines many separate, general purpose tasks the description given here refers to these tasks and leaves some of the details to their help documentation.

2. Usage Outline

[1] The images are first processed with **ccdproc** for overscan, bias, and dark corrections.

[2] Set the **do3fiber** parameters with **eparam**. Specify the object images to be processed, the flat field image as the aperture reference and the flat field, and one or more arc images. If there are many object or arc spectra per setup you might want to prepare "@ files".

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[3] Run the task. This may be repeated multiple times with different observations and the task will generally only do the setup steps once and only process new images. Queries presented during the execution for various interactive operations may be answered with "yes", "no", "YES", or "NO". The lower case responses apply just to that query while the upper case responses apply to all further such queries during the execution and no further queries of that type will be made.

[4] The apertures are defined using the specified aperture reference image which is usually a flat field in which both the object and arc fibers are illuminated. The specified number of fibers are found automatically and sequential apertures assigned.

[5] A query is given allowing the apertures to be interactively reviewed. In this mode one may adjust the aperture widths as desired either explicitly (:lower and :upper), with the cursor ('l' and 'u'), at a particular flux level ('y'), or with an automatic algorithm ('z') as described by **apresize**. To exit type 'q'.

[6] The fiber positions at a series of points along the dispersion are measured and a function is fit to these positions. This may be done interactively to adjust the fitting parameters. Not all fibers need be examined and the "NO" response will quit the interactive fitting. To exit the interactive fitting type 'q'.

[7] If flat fielding is to be done the flat field spectra are extracted. The average spectrum over all fibers is determined and a function is fit interactively (exit with 'q'). This function is generally of sufficiently high order that the overall shape is well fit. This function is then used to normalize the individual flat field spectra. The final response spectra are normalized to a unit mean over all fibers.

[8] If dispersion correction is selected the first arc in the arc list is extracted. The middle fiber is used to identify the arc lines and define the dispersion function using the task **identify**. Identify a few arc lines with 'm' and use the 'l' line list identification command to automatically add additional lines and fit the dispersion function. Check the quality of the dispersion function fit with 'f'. When satisfied exit with 'q'.

[9] The remaining fibers are automatically reidentified. You have the option to review the line identifications and dispersion function for each fiber and interactively add or delete arc lines and change fitting parameters. This can be done selectively, such as when the reported RMS increases significantly.

[10] If the spectra are to be resampled to a linear dispersion system (which will be the same for all spectra) default dispersion parameters are printed and you are allowed to adjust these as desired.

[11] The object spectra are now automatically extracted, flat fielded, and dispersion corrected. The reference apertures are first assigned to the object spectra. If the `recenter` option is set the apertures will have a shift applied based on recentering the fiber profiles. If the `edit` option is set you may review and modify the aperture definitions interactively. Any new arcs assigned to the object images are automatically extracted and dispersion functions determined. A zero point wavelength correction is computed from the arc fiber spectra and applied to the object spectrum.

[12] The option to examine the final spectra with **splot** may be given. To exit type 'q'.

[13] The final spectra will have the same name as the original 2D images with a ".ms" extension added.

3. Spectra and Data Files

The basic input consists of multifiber object and calibration spectra stored as IRAF images. There are two types of calibration images. These are flat fields and comparison lamp arc spectra. The raw CCD images must be processed to remove overscan, bias, and dark count effects. This is generally done using the **ccdred** package. Flat fielding is generally not done at this stage but as part of **do3fiber**. If for some reason the flat field or calibration arc spectra have separate exposures through different fibers they may be simply added.

The assignment of arc calibration exposures to object exposures is generally done by selecting the nearest in time and interpolating. However, the optional *arc assignment table* may be used to explicitly assign arc images to specific objects. The format of this file is described in the task **refspectra**.

The final reduced spectra are recorded in one, two or three dimensional IRAF images. The images have the same name as the original images with an added ".ms" extension. Each line in the reduced image is a one dimensional spectrum with associated aperture, wavelength, and identification information. With a single object spectrum the image will be one dimensional and with multiple object spectra the image will be two dimensional. When the `extras` parameter is set the images will be three dimensional (regardless of the number of apertures) and the lines in the third dimension contain additional information (see **apsum** for further details). These spectral formats are accepted by the one dimensional spectroscopy tasks such as the plotting tasks **splot** and **specplot**.

4. Package Parameters

The **kpnocoude** package parameters, shown in Figure 1, set parameters affecting all the tasks in the package. Some of the parameters are not applicable to the **do3fiber** task.

Figure 1: Package Parameters for KPNOCOUDE

```
                          I R A F
            Image Reduction and Analysis Facility
PACKAGE = imred
   TASK = kpnocoude

(extinct= onedstds$kpnoextinct.dat) Extinction file
(caldir = onedstds$spec50cal/) Standard star calibration directory
(observa=  observatory) Observatory of data
(interp =        poly5) Interpolation type
(dispaxi=            2) Image axis for 2D images
(nsum   =            1) Number of lines/columns to sum for 2D images

(databas=     database) Database
(verbose=           no) Verbose output?
(logfile=      logfile) Log file
(plotfil=             ) Plot file

(records=                     ) Record number extensions
(version= KPNOCOUDE V3: January 1992)
```

The observatory parameter is only required for data without an OBSERVAT header parameter (currently included in NOAO data). The spectrum interpolation type might be changed to "sinc" but with the cautions given in **onedspec.package**. The dispersion axis parameter is only needed if a DISPAXIS image header parameter is not defined. The other parameters define the standard I/O functions. The verbose parameter selects whether to print everything which goes into the log file on the terminal. It is useful for monitoring what the **do3fiber** task does. The log and plot files are useful for keeping a record of the processing. A log file is highly recommended. A plot file provides a record of apertures, traces, and extracted spectra but can become quite large. The plotfile is most conveniently viewed and printed with **gkimosaic**.

5. Processing Parameters

The **do3fiber** parameters are shown in Figure 2.

Figure 2: Parameter Set for DO3FIBER

```
                          I R A F
            Image Reduction and Analysis Facility
PACKAGE = kpnocoude
   TASK = do3fiber

objects =               List of object spectra
(apref  =             ) Aperture reference spectrum
(flat   =             ) Flat field spectrum
(arcs   =             ) List of arc spectra
(arctabl=             ) Arc assignment table (optional)

(readnoi=      RDNOISE) Read out noise sigma (photons)
(gain   =         GAIN) Photon gain (photons/data number)
(dispaxi=  )_.dispaxis) Dispersion axis (1=along lines, 2=along columns)
(fibers =            3) Number of fibers
(width  =           6.) Width of profiles (pixels)
(objaps =            2) Object apertures
(arcaps =          1,3) Arc apertures
```

```
(fitflat=          yes) Fit and ratio flat field spectrum?
(recente=          yes) Recenter object apertures?
(edit   =           no) Edit/review object apertures?
(clean  =           no) Detect and replace bad pixels?
(dispcor=          yes) Dispersion correct spectra?
(splot  =          yes) Plot the final spectrum?
(redo   =           no) Redo operations if previously done?
(update =          yes) Update spectra if cal data changes?
(batch  =           no) Extract objects in batch?
(listonl=           no) List steps but don't process?

(params =              ) Algorithm parameters
```

The input images are specified by image lists. The lists may be a list of explicit, comma separate image names, @ files, or image templates using pattern matching against file names in the directory. The aperture reference spectrum is used to find the spectrum profiles and trace them. Thus, this requires an image with good signal in all fibers which usually means a flat field spectrum. It is recommended that flat field correction be done using one dimensional extracted spectra rather than as two dimensional images. This is done if a flat field spectrum is specified. The arc assignment table is used to specifically assign arc spectra to particular object spectra and the format of the file is described in **refspectra**.

The detector read out noise and gain are used for cleaning and variance (optimal) extraction. The dispersion axis defines the wavelength direction of spectra in the image if not defined in the image header by the keyword DISPAXIS. The width parameter (in pixels) is used for the profile finding and centering algorithm (**center1d**).

The number of fibers is fairly obvious. It is the number of fibers, including the arc fibers, to be automatically found and assigned apertures. The apertures are assigned aperture numbers sequentially. The object and arc fibers are identified by these aperture numbers as specified by the `objaps` and `arcaps` parameters. The defaults are for the case of three fibers in the sequence arc fiber, object fiber, and arc fiber.

The next set of parameters select the processing steps and options. The flat fitting option allows fitting and removing the overall shape of the flat field spectra while preserving the pixel-to-pixel response corrections. This is useful for maintaining the approximate object count levels and not introducing the reciprocal of the flat field spectrum into the object spectra.

The apertures defined for the aperture reference image are assigned to each image. For the object images the apertures may be shifted across the dispersion by recentering the strongest profiles and averaging the individual shifts to form a single shift for all apertures. This corrects for shifts in the detector during the observations. The `recenter` parameter selects whether to apply this shift or not.

The `edit` option allows you to be queried to review the apertures assigned to each object image. If selected and the query answered affirmatively the apertures may be interactively shifted and resized. The query may also be answered with "NO" to turn off this option during processing. Note that the initial aperture definitions for the aperture reference image always allows editing.

The `clean` option invokes a profile fitting and deviant point rejection algorithm as well as a variance weighting of points in the aperture. These options require knowing the effective (i.e. accounting for any image combining) read out noise and gain. For a discussion of cleaning and variance weighted extraction see **apvariance** and **approfiles**.

The dispersion correction option selects whether to extract arc spectra, determine dispersion functions, assign them to the object spectra, and, possibly, resample the spectra to a linear (or log-linear) wavelength scale.

The `splot` option allows a query (which may be answered with "YES" or "NO" to eliminate the query) and then plotting of the final object spectra if answered affirmatively. The plotting is done with the task **splot**.

Generally once a spectrum has been processed it will not be reprocessed if specified as an input spectrum. However, changes to the underlying calibration data can cause such spectra to be reprocessed if the `update` flag is set. The changes which will cause an update are a new reference image, new flat field, and a new arc reference image. If all input spectra are to be processed regardless of previous processing the `redo` flag may be used. Note that reprocessing clobbers the previously processed output spectra.

The `batch` processing option allows object spectra to be processed as a background or batch job. This will only occur if the aperture editing and final spectrum plotting have been turned off, either with the task option parameter or by answering "NO" to the queries. The `listonly` option prints a summary of the processing steps which will be performed on the input spectra without actually doing anything. This is useful for verifying which spectra will be affected if the input list contains previously processed spectra. The listing does not include any arc spectra which

may be extracted to dispersion calibrate an object spectrum.

The last parameter (excluding the task mode parameter) points to another parameter set for the algorithm parameters. The way **do3fiber** works this may not have any value and the parameter set **params** is always used. The algorithm parameters are discussed further in the next section.

6. Algorithms and Algorithm Parameters

This section summarizes the various algorithms used by the **do3fiber** task and the parameters which control and modify the algorithms. The algorithm parameters available to the user are collected in the parameter set **params**. These parameters are taken from the various general purpose tasks used by the **do3fiber** processing task. Additional information about these parameters and algorithms may be found in the help for the actual task executed. These tasks are identified in the parameter section listing in parenthesis. The aim of this parameter set organization is to collect all the algorithm parameters in one place separate from the processing parameters and include only those which are relevant for this type of data. The parameter values can be changed from the defaults by using the parameter editor,

```
cl> epar params
```

or simple typing `params`. The parameter editor can also be entered when editing the **do3fiber** parameters by typing `:e params` or simply `:e` if positioned at the `params` parameter. Figure 3 shows the parameter set.

Figure 3: Algorithm Parameter Set

```
                          I R A F
            Image Reduction and Analysis Facility
PACKAGE = kpnocoude
   TASK = params

(line   =        INDEF) Default dispersion line
(nsum   =           10) Number of dispersion lines to sum
(extras =           no) Extract sky, sigma, etc.?

                        -- DEFAULT APERTURE LIMITS --
(lower  =         -3.0) Lower aperture limit relative to center
(upper  =          3.0) Upper aperture limit relative to center

                        -- AUTOMATIC APERTURE RESIZING PARAMETERS --
(ylevel =         0.05) Fraction of peak or intensity for resizing

                        -- TRACE PARAMETERS --
(t_step =           10) Tracing step
(t_funct=      spline3) Trace fitting function
(t_order=            2) Trace fitting function order
(t_niter=            1) Trace rejection iterations
(t_low  =          3.0) Trace lower rejection sigma
(t_high =          3.0) Trace upper rejection sigma

                        -- APERTURE EXTRACTION PARAMETERS --
(weights=         none) Extraction weights (none|variance)
(pfit   =        fit1d) Profile fitting algorithm (fit1d|fit2d)
(lsigma =          3.0) Lower rejection threshold
(usigma =          3.0) Upper rejection threshold
(nsubaps=            1) Number of subapertures

                        -- FLAT FIELD FUNCTION FITTING PARAMETERS --
(f_inter=          yes) Fit flat field interactively?
(f_funct=      spline3) Fitting function
(f_order=           20) Fitting function order
```

```
                        -- ARC DISPERSION FUNCTION PARAMETERS --
(coordli= linelists$idhenear.dat) Line list
(match  =          10.) Line list matching limit in Angstroms
(fwidth =          3.5) Arc line widths in pixels
(cradius=           4.) Centering radius in pixels
(i_funct=     legendre) Coordinate function
(i_order=            3) Order of dispersion function
(i_niter=            3) Rejection iterations
(i_low  =           3.) Lower rejection sigma
(i_high =           3.) Upper rejection sigma
(refit  =          yes) Refit coordinate function when reidentifying?
(addfeat=           no) Add features when reidentifying?

                        -- AUTOMATIC ARC ASSIGNMENT PARAMETERS --
(select =       interp) Selection method for reference spectra
(sort   =           jd) Sort key
(group  =          ljd) Group key
(time   =           no) Is sort key a time?
(timewra=          17.) Time wrap point for time sorting

                        -- DISPERSION CORRECTION PARAMETERS --
(lineari=          yes) Linearize (interpolate) spectra?
(log    =           no) Logarithmic wavelength scale?
(flux   =          yes) Conserve flux?
```

6.1. Aperture Definitions

The first operation is to define the extraction apertures, which include the aperture width and position dependence with wavelength, for the object and arc fibers. This is done on a reference spectrum which is usually a flat field taken through both fibers. Other spectra will inherit the reference apertures and may apply a correction for any shift of the orders across the dispersion. The reference apertures are defined only once unless the `redo` option is set.

The selected number of fibers are found automatically by selecting the highest peaks in a cut across the dispersion. Apertures are assigned with a limits set by the `lower` and `upper` parameter and numbered sequentially. A query is then given allowing the apertures to be reviewed interactively. If answered affirmatively a cut across the orders is shown with the apertures marked and an interactive aperture editing mode is entered (see **apedit**). The main thing to be concerned about is that the aperture numbers agree with the `objaps` and `arcaps` definitions. The aperture numbers may be changed with the 'i' or 'o' keys. The apertures may also be resized from the default limits. To exit the background and aperture editing steps type 'q'.

Next the positions of the fiber profiles at various points along the dispersion are measured and a "trace function" is fit. The user is asked whether to fit the trace function interactively. This is selected to adjust the fitting parameters such as function type and order. When interactively fitting a query is given for each aperture. After the first aperture one may skip reviewing the other traces by responding with "NO". Queries made by **do3fiber** generally may be answered with either lower case "yes" or "no" or with upper case "YES" or "NO". The upper case responses apply to all further queries and so are used to eliminate further queries of that kind.

The above steps are all performed using tasks from the **apextract** package and parameters from the **params** parameters. As a quick summary, the dispersion direction of the spectra are determined from the **dispaxis** parameter if not defined in the image header. The default line or column for finding the orders and the number of image lines or columns to sum are set by the `line` and `nsum` parameters. A line of INDEF (the default) selects the middle of the image. The automatic finding algorithm is described for the task **apfind** and basically finds the strongest peaks. The tracing is done as described in **aptrace** and consists of stepping along the image using the specified `t_step` parameter. The function fitting uses the **icfit** commands with the other parameters from the tracing section.

6.2. Extraction

The actual extraction of the spectra is done by summing across the fixed width apertures at each point along the dispersion. The default is to simply sum the pixels using partial pixels at the ends. There is an option to weight the sum based on a Poisson noise model using the `readnoise` and `gain` detector parameters. Note that if the `clean` option is selected the variance weighted extraction is used regardless of the `weights` parameter. The sigma thresholds for cleaning are also set in the **params** parameters.

The cleaning and variance weighting options require knowing the effective (i.e. accounting for any image combining) read out noise and gain. These numbers need to be adjusted if the image has been processed such that the intensity scale has a different origin (such as a background light subtraction) or scaling (such as caused by unnormalized flat fielding). For optimal extraction and cleaning to work it is recommended that the `fitflat` option be used. For further discussion of cleaning and variance weighted extraction see **apvariance** and **approfiles** as well as **apsum**.

6.3. Flat Field Correction

Flat field corrections may be made during the basic CCD processing; i.e. direct division by the two dimensional flat field observation. In that case do not specify a flat field spectrum; use the null string "". The **do3fiber** task provides an alternative flat field response correction based on division of the extracted object spectra by the extracted flat field spectra. A discussion of the theory and merits of flat fielding directly verses using the extracted spectra will not be made here. The **do3fiber** flat fielding algorithm is the *recommended* method for flat fielding since it works well and is not subject to the many problems involved in two dimensional flat fielding.

The first step is extraction of the flat field spectrum, if specified, using the reference apertures. Only one flat field is allowed so if multiple flat fields are required the data must be reduced in groups. If the `fitflat` option is selected (the default) the extracted flat field spectra are averaged together and a smooth function is fit. The default fitting function and order are given by the parameters `f_function` and `f_order`. If the parameter `f_interactive` is "yes" then the fitting is done interactively using the **fit1d** task which uses the **icfit** interactive fitting commands.

The fitted function is divided into the individual flat field spectra to remove the basic shape of the spectrum while maintaining the relative individual pixel responses and any fiber to fiber differences. This step avoids introducing the flat field spectrum shape into the object spectra and closely preserves the object counts.

The final step is to normalize the flat field spectra by the mean counts over all the fibers. This normalization step is simply to preserve the average counts of the extracted object and arc spectra after division by the response spectra.

6.4. Dispersion Correction

If dispersion correction is not selected, `dispcor`=no, then the object spectra are simply extracted. If it is selected the arc spectra are used to dispersion calibrate the object spectra. There are four steps involved; determining the dispersion functions relating pixel position to wavelength, assigning the appropriate dispersion function to a particular observation, determining a zero point wavelength shift from the arc fibers to be applied to the object fiber dispersion functions, and either storing the nonlinear dispersion functions in the image headers or resampling the spectra to evenly spaced pixels in wavelength.

The first arc spectrum in the arc list is used to define the reference dispersion solution. It is extracted using the reference aperture definitions. The interactive task **identify** is used to define the dispersion function in one fiber. The idea is to mark some lines whose wavelengths are known (with the line list used to supply additional lines after the first few identifications define the approximate wavelengths) and to fit a function giving the wavelength from the pixel position. The dispersion functions for the other fibers are then determined automatically by reference to the first fiber using the task **reidentify**. Except in batch mode a query is given allowing the reidentified arc spectra to be examined interactively with **identify**. This would normally be done only if the information about the reidentification printed on the terminal indicates a problem such as a large increase in the RMS. This query may be eliminated in the usual way.

The set of arc dispersion function parameters are from **identify** and **reidentify**. The parameters define a line list for use in automatically assigning wavelengths to arc lines, a parameter controlling the width of the centering window (which should match the base line widths), the dispersion function type and order, parameters to exclude bad lines from function fits, and parameters defining whether to refit the dispersion function, as opposed to simply determining a zero point shift, and the addition of new lines from the line list when reidentifying additional arc spectra. The defaults should generally be adequate and the dispersion function fitting parameters may be altered interactively. One should consult the help for the two tasks for additional details of these parameters and the operation of **identify**.

If resampling of the spectra is selected by the parameter `linearize` all the arc dispersion functions are combined to provide a default starting and ending wavelength and dispersion with the same number of pixels is determined and the user is queried for any changes. This linear dispersion system will be applied to all spectra so that all the final processed object spectra will have the same dispersion sampling.

Once the reference dispersion functions are defined other arc spectra are extracted as they are assign to the object spectra. The assignment of arcs is done either explicitly with an arc assignment table (parameter `arctable`) or based on a header parameter such as a time. The assignments are made by the task **refspectra**. When two arcs are assigned to an object spectrum an interpolation is done between the two dispersion functions. This makes an approximate correction for steady drifts in the dispersion. Because the arc fibers monitor any zero point shifts in the

dispersion functions, due to translation and rotation of the detector, it is probably only necessary to have one or two arc spectra, one at the beginning and/or one at the end of the night.

The tasks **setjd** and **setairmass** are automatically run on all spectra. This computes and adds the header parameters for the Julian date (JD), the local Julian day number (LJD), the universal time (UTMIDDLE), and the air mass at the middle of the exposure. The default arc assignment is to use the Julian date grouped by the local Julian day number. The grouping allows multiple nights of data to be correctly assigned at the same time.

When the object spectra are extracted so are the simultaneous arc spectra. A zero point shift of the arc spectra relative to the dispersion solutions of an assigned full arc observation is computed using **reidentify**. The zero point shifts from the arc fibers are then interpolated across the detector based on the positions of the arc apertures to the positions of the object apertures. A linear interpolation is used which accounts for a rotation of the detector as well as a translation along the dispersion. The interpolated zero point wavelength shifts are then added to the dispersion functions from the full arc observation for the object fibers. Note that this does not assume that the object and arc fiber dispersion functions are the same or have the same wavelength origin, but only that the interpolated shifts in wavelength zero point apply to all fibers. When there are two assigned full arc spectra the above steps are done independently and the final pair of zero point corrected dispersion functions for each object fiber are combined using the assigned weights. Once the dispersion function correction is determined from the extracted arc fiber spectra they are deleted leaving only the object spectra.

The last step of dispersion correction is setting the dispersion of the object spectra. There are two choices here. If the `linearize` parameter is not set the nonlinear dispersion functions are stored in the image header. Other IRAF tasks interpret this information when dispersion coordinates are needed for plotting or analysis. This has the advantage of not requiring the spectra to be interpolated and the disadvantage that the dispersion information is only understood by IRAF tasks and cannot be readily exported to other analysis software.

If the `linearize` parameter is set then the spectra are resampled to a linear dispersion relation either in wavelength or the log of the wavelength. The linear dispersion parameters are those defined previously for the arc reference image.

The linearization algorithm parameters allow selecting the interpolation function type, whether to conserve flux per pixel by integrating across the extent of the final pixel, and whether to linearize to equal linear or logarithmic intervals. The latter may be appropriate for radial velocity studies. The default is to use a fifth order polynomial for interpolation, to conserve flux, and to not use logarithmic wavelength bins. These parameters are described fully in the help for the task **dispcor** which performs the correction.

7. References

7.1. IRAF Introductory References

Work is underway on a new introductory guide to IRAF. Currently, the work below is the primary introduction.

P. Shames and D. Tody, *A User's Introduction to the IRAF Command Language*, Central Computer Services, NOAO, 1986.

7.2. CCD Reductions

F. Valdes, *The IRAF CCD Reduction Package -- CCDRED*, Central Computer Services, NOAO, 1987.

F. Valdes, *User's Guide to the CCDRED Package*, Central Computer Services, NOAO, 1988. Also on-line as `help ccdred.guide`.

P. Massey, *A User's Guide to CCD Reductions with IRAF*, Central Computer Services, NOAO, 1989.

7.3. Aperture Extraction Package

F. Valdes, *The IRAF APEXTRACT Package*, Central Computer Services, NOAO, 1987 (out-of-date).

7.4. Task Help References

Each task in the **specred** packages and tasks used by **dofibers** have help pages describing the parameters and task in some detail. To get on-line help type

`cl> help` *taskname*

The output of this command can be piped to **lprint** to make a printed copy.

```
     apall - Extract 1D spectra (all parameters in one task)
  apdefault - Set the default aperture parameters
    apedit - Edit apertures interactively
    apfind - Automatically find spectra and define apertures
 aprecenter - Recenter apertures
  apresize - Resize apertures
     apsum - Extract 1D spectra
   aptrace - Trace positions of spectra

     bplot - Batch plot of spectra with SPLOT
  calibrate - Apply extinction and flux calibrations to spectra
  continuum - Fit and normalize the continuum of multispec spectra
  deredden - Apply interstellar extinction corrections
   dispcor - Dispersion correct spectra
    dopcor - Doppler correct spectra
  identify - Identify arc lines and determine a dispersion function
  msresp1d - Create fiber response spectra from flat field and sky spectra
 refspectra - Assign reference spectra to observations
 reidentify - Reidentify arc lines and determine new dispersion functions
 sapertures - Set or change aperture header information
    sarith - Spectrum arithmetic
  scombine - Combine spectra
     scopy - Copy spectra including aperture selection and format changes
  sensfunc - Create sensitivity function
 setairmass - Compute effective airmass and middle UT for an exposure
     setjd - Compute and set Julian dates in images
     slist - List spectrum headers
  specplot - Stack and plot multiple spectra
     splot - Plot and analyze spectra
  standard - Identify standard stars to be used in sensitivity calc

  do3fiber - Process KPNO coude three fiber spectra
     demos - Demonstrations and tests

           Additional help topics

  onedspec.package - Package parameters and general description of package
 apextract.package - Package parameters and general description of package
 approfiles - Profile determination algorithms
 apvariance - Extractions, variance weighting, cleaning, and noise model
  center1d - One dimensional centering algorithm
     icfit - Interactive one dimensional curve fitting
```

Appendix A: DO3FIBER Parameters

objects

List of object spectra to be processed. Previously processed spectra are ignored unless the `redo` flag is set or the `update` flag is set and dependent calibration data has changed. Extracted spectra are ignored.

apref = ""

Aperture reference spectrum. This spectrum is used to define the basic extraction apertures and is typically a flat field spectrum.

flat = "" (optional)

Flat field spectrum. If specified the one dimensional flat field spectra are extracted and used to make flat field corrections.

arcs = "" (at least one if dispersion correcting)

List of primary, all fiber arc spectra. These spectra are used to define the dispersion functions for each fiber apart from a possible zero point correction made with simultaneous arc calibration fibers in the object spectra. One fiber from the first spectrum is used to mark lines and set the dispersion function interactively and dispersion functions for all other fibers and arc spectra are derived from it.

arctable = "" (optional) (refspectra)
Table defining arc spectra to be assigned to object spectra (see **refspectra**). If not specified an assignment based on a header parameter, `params.sort`, such as the observation time is made.

readnoise = "RDNOISE" (apsum)
Read out noise in photons. This parameter defines the minimum noise sigma. It is defined in terms of photons (or electrons) and scales to the data values through the gain parameter. A image header keyword (case insensitive) may be specified to get the value from the image.

gain = "GAIN" (apsum)
Detector gain or conversion factor between photons/electrons and data values. It is specified as the number of photons per data value. A image header keyword (case insensitive) may be specified to get the value from the image.

dispaxis = ")_.dispaxis" (apextract)
Default dispersion axis. The dispersion axis is 1 for dispersion running along image lines and 2 for dispersion running along image columns. If the image header parameter DISPAXIS is defined it has precedence over this parameter. The default value defers to the package parameter of the same name.

fibers = 3 (apfind)
Number of fibers. This number is used during the automatic definition of the apertures from the aperture reference spectrum.

width = 6. (apedit)
Approximate base full width of the fiber profiles. This parameter is used for the profile centering algorithm.

objaps = "2", arcaps = "1,3"
List of object and arc aperture numbers. These are used to identify arc apertures for wavelength calibration and object apertures for the final results.

fitflat = yes (flat1d)
Fit the composite flat field spectrum by a smooth function and divide each flat field spectrum by this function? This operation removes the average spectral signature of the flat field lamp from the sensitivity correction to avoid modifying the object fluxes.

recenter = yes (aprecenter)
Recenter reference apertures for each object spectrum?

edit = no (apedit)
Review aperture definitions for each object spectrum? Note that this does not apply to the initial reference aperture which always allows interactive review of the aperture definitions.

clean = no (apsum)
Detect and correct for bad pixels during extraction? This is the same as the clean option in the **apextract** package. If yes this also implies variance weighted extraction and requires reasonably good values for the readout noise and gain.

dispcor = yes
Dispersion correct spectra? Depending on the `params.linearize` parameter this may either resample the spectra or insert a dispersion function in the image header.

splot = yes
Plot the final spectra with the task **splot**?

redo = no
Redo operations previously done? If no then previously processed spectra in the objects list will not be processed (unless they need to be updated).

update = yes
Update processing of previously processed spectra if aperture, flat field, or dispersion reference definitions are changed?

batch = no
Process spectra as a background or batch job provided there are no interactive options (`edit` and `splot`)

selected.

listonly = no
List processing steps but don't process?

params = "" (pset)
Name of parameter set containing additional processing parameters. The default is parameter set **params**. The parameter set may be examined and modified in the usual ways (typically with "epar params" or ":e params" from the parameter editor). Note that using a different parameter file is not allowed. The parameters are described below.

-- PACKAGE PARAMETERS

Package parameters are those which generally apply to all task in the package. This is also true of **do3fiber**.

observatory = "observatory"
Observatory at which the spectra were obtained if not specified in the image header by the keyword OBSERVAT. For NOAO data the image headers identify the observatory as "kpno" or "ctio" so this parameter is not used. For data from other observatories this parameter may be used as describe in **observatory**.

interp = "poly5" (nearest|linear|poly3|poly5|spline3|sinc)
Spectrum interpolation type used when spectra are resampled. The choices are:

```
    nearest - nearest neighbor
     linear - linear
      poly3 - 3rd order polynomial
      poly5 - 5th order polynomial
    spline3 - cubic spline
       sinc - sinc function
```

dispaxis = 2
Default dispersion axis. The dispersion axis is 1 for dispersion running along image lines and 2 for dispersion running along image columns. If the image header parameter DISPAXIS is defined it has precedence over this parameter.

database = "database"
Database (directory) used for storing aperture and dispersion information.

verbose = no
Print verbose information available with various tasks.

logfile = "logfile", plotfile = ""
Text and plot log files. If a filename is not specified then no log is kept. The plot file contains IRAF graphics metacode which may be examined in various ways such as with **gkimosaic**.

records = ""
Dummy parameter to be ignored.

version = "KPNOCOUDE: ..."
Version of the package.

PARAMS PARAMETERS

The following parameters are part of the **params** parameter set and define various algorithm parameters for **do3fiber**.

-- GENERAL PARAMETERS --

line = INDEF, nsum = 10
The dispersion line (line or column perpendicular to the dispersion axis) and number of adjacent lines (half before and half after unless at the end of the image) used in finding, recentering, resizing, editing, and tracing operations. A line of INDEF selects the middle of the image along the dispersion axis.

extras = no (apsum)
Include extra information in the output spectra? When cleaning or using variance weighting the cleaned and weighted spectra are recorded in the first 2D plane of a 3D image, the raw, simple sum spectra are recorded in the second plane, and the estimated sigmas are recorded in the third plane.

-- DEFAULT APERTURE LIMITS --

lower = -3., upper = 3. (apdefault)
Default lower and upper aperture limits relative to the aperture center. These limits are used when the apertures are first found and may be resized automatically or interactively.

-- AUTOMATIC APERTURE RESIZING PARAMETERS --

ylevel = 0.05 (apresize)
Data level at which to set aperture limits during automatic resizing. It is a fraction of the peak relative to a local background.

-- TRACE PARAMETERS --

t_step = 10 (aptrace)
Step along the dispersion axis between determination of the spectrum positions. Note the `nsum` parameter is also used to enhance the signal-to-noise at each step.

t_function = "spline3", t_order = 2 (aptrace)
Default trace fitting function and order. The fitting function types are "chebyshev" polynomial, "legendre" polynomial, "spline1" linear spline, and "spline3" cubic spline. The order refers to the number of terms in the polynomial functions or the number of spline pieces in the spline functions.

t_niterate = 1, t_low = 3., t_high = 3. (aptrace)
Default number of rejection iterations and rejection sigma thresholds.

-- APERTURE EXTRACTION PARAMETERS --

weights = "none" (apsum)
Type of extraction weighting. Note that if the `clean` parameter is set then the weights used are "variance" regardless of the weights specified by this parameter. The choices are:

"none"
The pixels are summed without weights except for partial pixels at the ends.

"variance"
The extraction is weighted by the variance based on the data values and a poisson/ccd model using the `gain` and `readnoise` parameters.

pfit = "fit1d" (apsum) (fit1d|fit2d)
Profile fitting algorithm for cleaning and variance weighted extractions. The default is generally appropriate for most data but users may try the other algorithm. See **approfiles** for further information.

lsigma = 3., usigma = 3. (apsum)
Lower and upper rejection thresholds, given as a number of times the estimated sigma of a pixel, for cleaning.

nsubaps = 1 (apsum)
During extraction it is possible to equally divide the apertures into this number of subapertures.

-- FLAT FIELD FUNCTION FITTING PARAMETERS --

f_interactive = yes (fit1d)
Fit the composite one dimensional flat field spectrum interactively? This is used if `fitflat` is set and a two dimensional flat field spectrum is specified.

f_function = "spline3", f_order = 20 (fit1d)
Function and order used to fit the composite one dimensional flat field spectrum. The functions are "legendre", "chebyshev", "spline1", and "spline3". The spline functions are linear and cubic splines with the order specifying the number of pieces.

-- ARC DISPERSION FUNCTION PARAMETERS --

coordlist = "linelists$idhenear.dat" (identify)
Arc line list consisting of an ordered list of wavelengths. Some standard line lists are available in the directory "linelists$".

match = 10. (identify)
The maximum difference for a match between the dispersion function prediction value and a wavelength in the coordinate list.

fwidth = 3.5 (identify)
Approximate full base width (in pixels) of arc lines.

cradius = 4. (reidentify)
Radius from previous position to reidentify arc line.

i_function = "legendre", i_order = 3 (identify)
The default function and order to be fit to the arc wavelengths as a function of the pixel coordinate. The functions choices are "chebyshev", "legendre", "spline1", or "spline3".

i_niterate = 3, i_low = 3.0, i_high = 3.0 (identify)
Number of rejection iterations and sigma thresholds for rejecting arc lines from the dispersion function fits.

refit = yes (reidentify)
Refit the dispersion function? If yes and there is more than 1 line and a dispersion function was defined in the arc reference then a new dispersion function of the same type as in the reference image is fit using the new pixel positions. Otherwise only a zero point shift is determined for the revised fitted coordinates without changing the form of the dispersion function.

addfeatures = no (reidentify)
Add new features from a line list during each reidentification? This option can be used to compensate for lost features from the reference solution. Care should be exercised that misidentified features are not introduced.

-- AUTOMATIC ARC ASSIGNMENT PARAMETERS --

select = "interp" (refspectra)
Selection method for assigning wavelength calibration spectra. Note that an arc assignment table may be used to override the selection method and explicitly assign arc spectra to object spectra. The automatic selection methods are:

average
Average two reference spectra without regard to any sort parameter. If only one reference spectrum is specified then it is assigned with a warning. If more than two reference spectra are specified then only the first two are used and a warning is given. This option is used to assign two reference spectra, with equal weights, independent of any sorting parameter.

following
Select the nearest following spectrum in the reference list based on the sorting parameter. If there is no following spectrum use the nearest preceding spectrum.

interp
Interpolate between the preceding and following spectra in the reference list based on the sorting parameter. If there is no preceding and following spectrum use the nearest spectrum. The interpolation is weighted by the relative distances of the sorting parameter.

match
Match each input spectrum with the reference spectrum list in order. This overrides the reference aperture check.

nearest
Select the nearest spectrum in the reference list based on the sorting parameter.

preceding
Select the nearest preceding spectrum in the reference list based on the sorting parameter. If there is no preceding spectrum use the nearest following spectrum.

sort = "jd", group = "ljd" (refspectra)
Image header keywords to be used as the sorting parameter for selection based on order and to group spectra. A null string, "", or the word "none" may be use to disable the sorting or grouping parameters. The sorting parameter must be numeric but otherwise may be anything. The grouping parameter may be a string or number and must simply be the same for all spectra within the same group (say a single night). Common sorting parameters are times or positions. In **do3fiber** the Julian date (JD) and the local Julian day number (LJD) at the middle of the exposure are automatically computed from the universal time at the beginning of the exposure and the exposure time. Also the parameter UTMIDDLE is computed.

time = no, timewrap = 17. (refspectra)
Is the sorting parameter a 24 hour time? If so then the time origin for the sorting is specified by the timewrap parameter. This time should precede the first observation and follow the last observation in a 24 hour cycle.

-- DISPERSION CORRECTION PARAMETERS --

linearize = yes (dispcor)
Interpolate the spectra to a linear dispersion sampling? If yes the spectra will be interpolated to a linear or log linear sampling If no the nonlinear dispersion function(s) from the dispersion function database are assigned to the input image world coordinate system and the spectral data are not interpolated.

log = no (dispcor)
Use linear logarithmic wavelength coordinates? Linear logarithmic wavelength coordinates have wavelength intervals which are constant in the logarithm of the wavelength.

flux = yes (dispcor)
Conserve the total flux during interpolation? If `no` the output spectrum is interpolated from the input spectrum at each output wavelength coordinate. If `yes` the input spectrum is integrated over the extent of each output pixel. This is slower than simple interpolation.