CORONAL DIAGNOSTIC SPECTROMETER
SoHO

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CDS QUICKLOOK SOFTWARE
— USER MANUAL —

P. Brekke and S. V. H. Haugan
Institute of Theoretical Astrophysics
University of Oslo
P.O.Box 1029, Blindern
N-0315 Oslo, NORWAY

INSTITUTE OF THEORETICAL ASTROPHYSICS
UNIVERSITY OF OSLO
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1 Introduction

1.1 About the Quicklook software

The CDS Quicklook software package presented here is designed to display and manipulate data from the Coronal Diagnostic Spectrometer (CDS) on SOHO. The software uses IDL widgets to lower the threshold for new users and to function as a helpful tool during operations, quickly browsing through newly received data from CDS to assist further planning of new observing sequences.

The Quicklook software may function as a nice starting point for analysis of data, to get an overview of the data at hand. It also supplies routines interfacing with the data structure to simplify the task of writing analysis programs suited to specific observations.

1.2 About this manual

This manual is meant as an overview on how to get started and how to use the Quicklook software to inspect CDS data. It does not include any details about the code itself, but points out most of the useful features.

Once you get going, *don't be shy* — it's generally a lot quicker to press a button to see what it does rather than trying to look it up in this manual, and there's just about no way you can do anything harmful.

Each CDS routine contains a header describing details about the routine, how to use it, input parameters, what other routines are called etc. The header information of a given CDS routine can be displayed calling different help routines available in the CDS software package (e.g. `XDOC`, see Section 2).

This document starts with an overview of some very useful general software and help routines, and a brief introduction to the CDS instrument and the data format. Then the CDS FITS files and the CDS data structure within IDL are briefly discussed.

The main part of the document gives an introduction to the Quicklook software and how to get started. This section is followed by some examples on how to extract and display the CDS data directly from the IDL prompt, to allow personal creativity to be used as well as personal routines.

Other useful documents that can be of help for the user of the CDS Software include:

- CDS Science Report (Blue book), 1993, R. A. Harrison, RAL.
- CDS Software notes (see Appendix A).
- IDL User Manual

A set of routines to support the interoperability between SOHO instruments has also been developed and is called the CDS Interoperability Software. The objective of this software is to allow other SOHO instrument teams to read and display CDS data. The software has deliberately been written so that a minimum of CDS library routines will be needed to support them. A full description of this software is given in CDS Software Note No. 18 (Thompson, 1994)

2 Setup, On-line help & useful routines

2.1 Setup

The CDS Quicklook software relies on a large number of routines in the CDS software tree, on environment variables pointing to data files, and on some IDL system variables to function correctly. For instructions on how to install the CDS software, we refer to CDS Software Note No. 17, *Installing the CDS software*.

The CDS software tree includes software for retrieving the telemetry, reading and writing to FITS files, display and analysis routines etc. For more details about the directory structure we refer to CDS Software Note No. 8, *Software and Data Directories* (Pike, 1993). Each directory which contains some files should have a `aaareadme.txt` file which explains the general purpose behind the files in that directory.

2.2 On-line help & useful routines

Each CDS routine contains a documentation header with information about the routine, the calling syntax, other routines being called and a modification history (see CDS Software Note No. 22 (Pike 1994). The header documentation should be informative enough to act as a reminder or to answer most general questions about the programs, and the header documentation is more likely to be up-to-date than software notes.

A set of routines has been designed to help give the user access to on-line help (see CDS Software Note No. 22 for more details). New users are recommended to play with these routines to get familiar with the CDS software and to search for useful programs.

`XDOC`

A widget-based routine browser for X-windows users. The routine is used to display the documentation header as well as the source code if requested. Documentation from any routine found in !PATH can be displayed with XDOC.

`CHKARG`

Returns the arguments of a named procedure.

`PURPOSE`

Produce a list of the program names and the one-line entries after "PURPOSE" in the routine's documentation header.

`CHECK_CONFLICT`

Check and report if there are any duplicate file names in the IDL search path.

`WHICH`

Use to find where IDL finds a program file. This program is useful to check if you are running the version you really want.

`TFTD`

Use to list a number of documentation one-liners or to search for a given text string in the names of available routines or in their one-line help.

SHOW_STRUCT
: provides an easy and quick graphical way to peruse all levels of a structure variable.

XPL_STRUCT
: is similar to SHOW_STRUCT, but when selecting an item from the pulldown menu showing the structure, it will call a help widget (WIDG_HELP) to display some information on the structure/tag chosen. For this to work, the structure must be described in the file struct_tags.hlp, which must be located in the IDL path.

We strongly recommend the use of XDOC to obtain information about the various routines in the CDS directory. The XDOC routine can also be useful to browse the CDS software tree and to search for useful programs.

Following are some examples of how to use some of the above routines.

The routine tftd is useful when you don't remember the exact name of a routine, but you can make an educated guess about a phrase that the name or purpose contains:

```
IDL> tftd,'dsp'         ; Let's say you're trying to locate a display routine

Thoughts for the day produced by TFTD q.v.

CDSPICKFILE       - This function allows the user to interactively pick a file
CWQ_DSPWAV        - Constitutes one column of the data display in DSPWAV.
DSPEXP            - Display all exposures of selected Spectral Windows.
DSPSPEC()         - Displays all Spectral Windows from specific exposures.
DSPWAV            - Display data slices at specific wavelength +line profiles
DSP_AUX           - Plot/display auxiliary data from a qlds.
DSP_INFO          - Display basic information from a CDS QL Data Structure
DSP_MENU          - Selection of display modes for CDS QL data.
DSP_MOVIE         - Display a movie of CDS "slit spectrograms" (SCANX/Y/T)
DSP_POINT         - Show pointing area for QLDS with IMAGE_TOOL
DSP_RASTER        - Displays locations of CDS raster using IMAGE_TOOL.
DSP_STRARR        - To display a string array in a text widget.
DSP_STRUCT        - Display contents of a structure as a pulldown menu.
DSP_WAV           - Show images at given wavelengths + spectra at given point
GDSPSPEC          - Displays all spectral windows from specific exposures.
NDSPSPEC()        - Displays all Spectral Windows from specific exposures.
```

The routine **chkarg** is useful if you know the name of a routine but can't remember whether it's a function or procedure or want a quick route to checking its parameters and keywords:

```
IDL> chkarg,'dsp_point
---- Module: dsp_point.pro
---- From:   /mn/achernar/u2/cds/fcs
---> Call: PRO dsp_point,qlds,modal=modal,group=group,xix=xix,yix=yix,$
accumulate=accumulate,fov=fov,point_stc=point_stc,$
no_rotation=no_rotation,soho_view=soho_view,unfold=unfold
```

For users who are intending to create new procedures or functions and wish to avoid creating program names which duplicate an existing one, which provides a quick and easy check for existing names. It also provides you with information about which copy IDL actually was using, your own *modified* version or the *old* version in the CDS library.

```
IDL> which, 'purpose'       ; Determine which routine IDL is picking up

/cds/util/help/purpose.pro  ; Resulting output
```

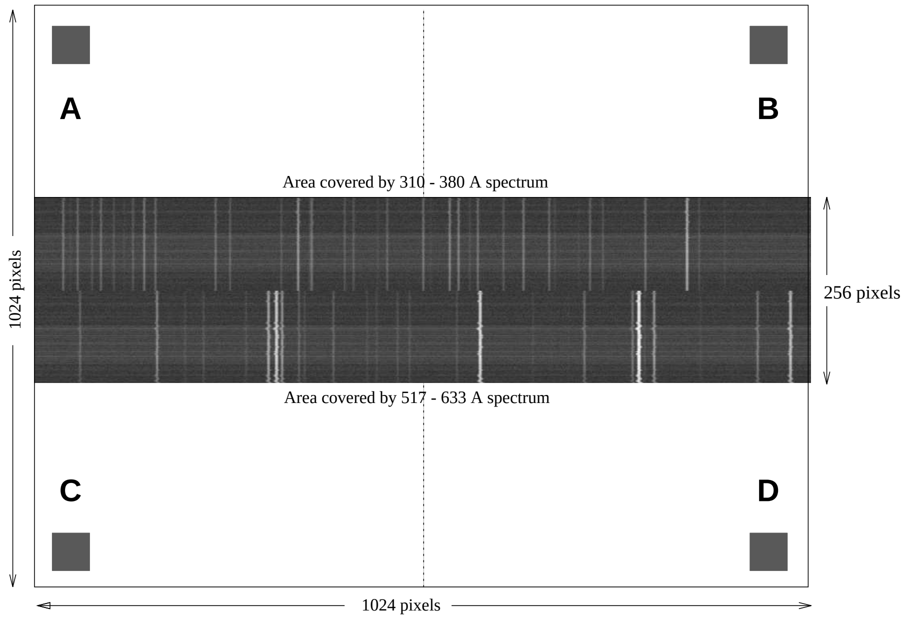


Figure 1: Schematic illustration of the NIS detector where the two normal incidence spectra are focused onto the center portion of the detector. Thus, only the central 1024×256 pixel area is used.

We should also mention a general software package called the SERTS Image Display Routines and the SERTS Graphics Device Routines. The software is described in CDS Software Notes No. 5 and 6 (Thompson 1993b, 1993c). A few examples of this software will be given in Section 5.6.

3 The CDS Instrument

The Coronal Diagnostic Spectrometer (CDS) consists of a Wolter-Schwartschild II grazing incidence telescope which has the focus at a slit assembly which lies beyond a flat scan mirror. After the slit, two components of the beam are fed into two spectrometers. One component feeds a normal incidence spectrometer (NIS) with a twin toroidal grating assembly and a 2-D detector. Another part of the beam is fed to a grazing incidence spectrometer (GIS) with a spherical grating and an array of four 1-D detectors along the Rowland Circle.

The NIS detector consists of 1024 $\times$ 1024 pixels. Two spectra are imaged onto the CCD, offset on either side of the horizontal center-line as shown in Figure 1. The spectral coverage is approximately 310–380 Å and 517–633 Å The longest slits are 240 arcseconds in length which, at a plate scale of 12.5 micron/arcsec, translates to 3 mm on the detector. Thus, only the central 1024 $\times$ 256 pixel area (approximately) is used. The horizontal direction is the direction of spectral dispersion while the vertical direction is the spatial dimension along the slit.

In practice, it will be rare that CDS can return the full NIS detector output due to the limited telemetry rates available. In most cases a selection of data will be used, to limit the telemetry requirements, where a set of detector data windows, or line windows (since the windows are usually centered around emission lines) will be extracted from the full detector. An example of a typical line selection is shown in Figure 2 where 12 windows have been selected.

The GIS spectrum is focused into four 1-D detectors and cover the wavelength ranges 155-244

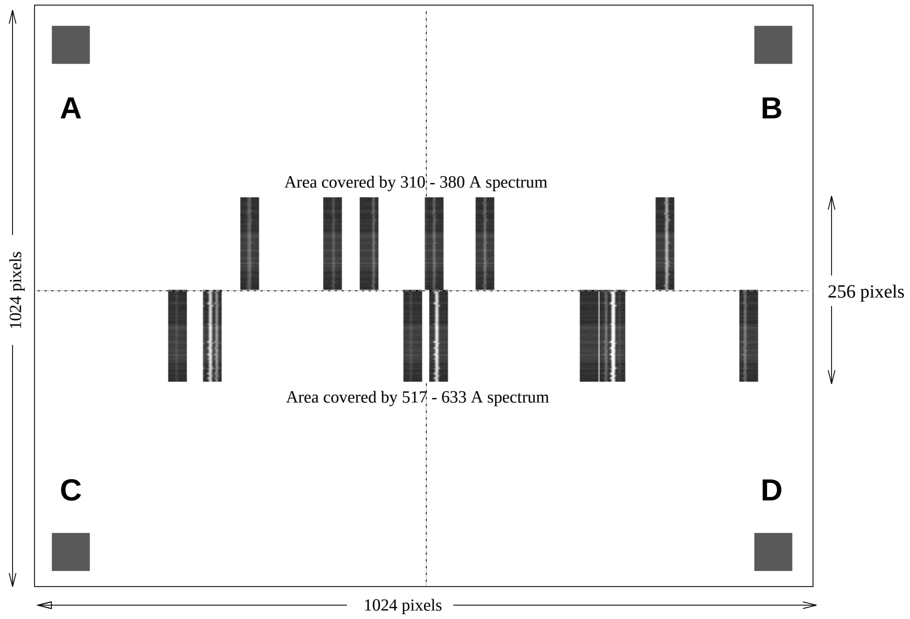


Figure 2: In most cases only selected line windows will be transmitted to ground. The illustration shows a typical line selection from the NIS detector.

Å, 261–346 Å, 395–496 Å, and 662–787 Å. Figure 3 gives an example of a synthetic GIS spectrum As for the NIS detector a selection of line windows can be extracted from the four GIS detectors. A summary of line lists to be used during different observing sequences can be found in the CDS Blue Book.

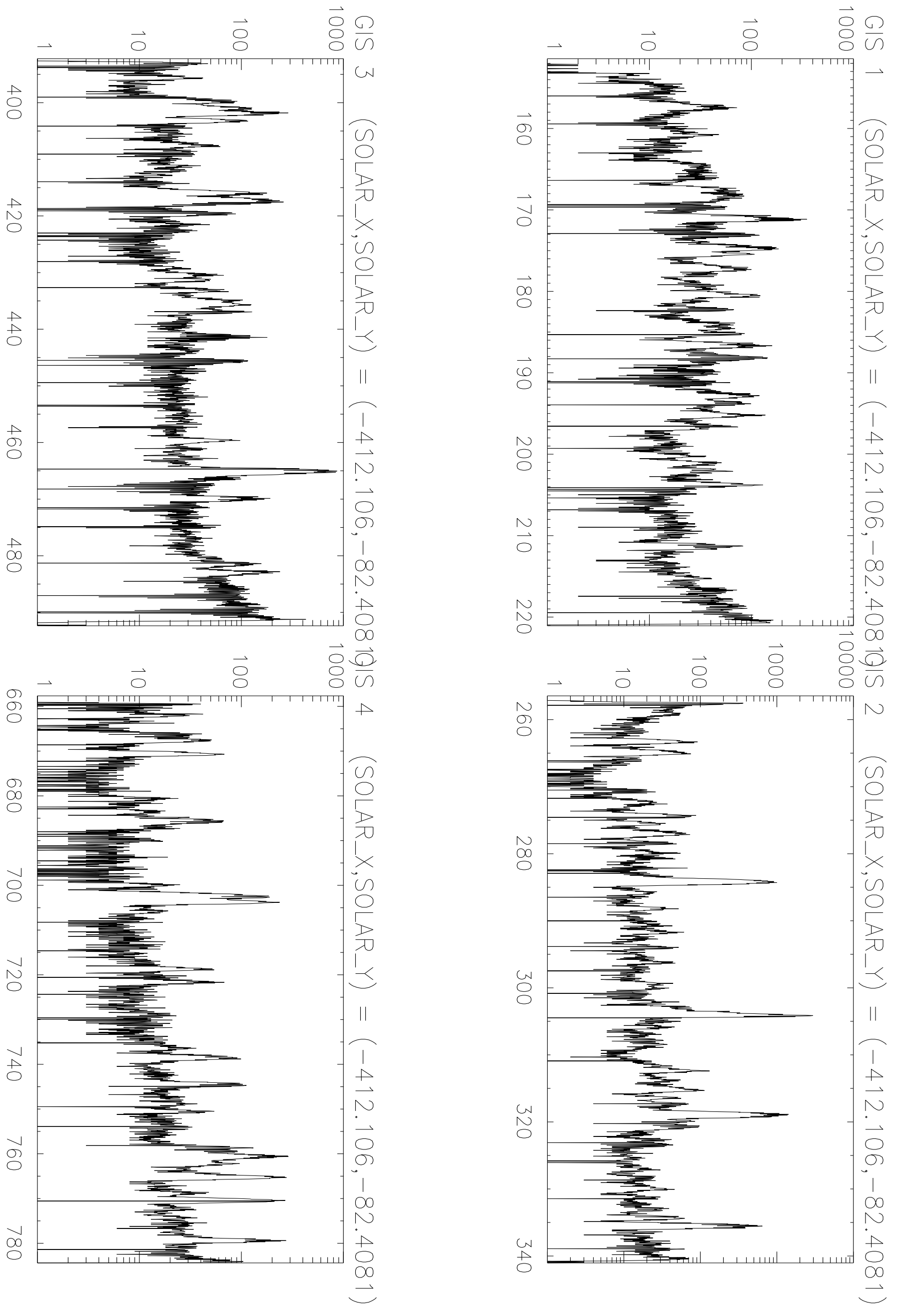


Figure 3: Example of a GIS spectrum showing the four detectors in individual plots.

4 CDS Data formats - data structure

4.1 Rasters

A *raster* is a series of GIS or NIS exposures grouped together as one observation "unit". Rasters may be

- Single exposures, yielding a single spectrum (for the GIS) or a single slit spectrogram (for the NIS).
- Repeated exposures at the same position, yielding a time series of spectra/slit spectrograms.
- A spatial scan covering an extended area, with one spectrum at each pixel position.

A schematic illustration of a raster is shown in Figure 4, where the length of the slit is 240 arcsec (120 pixels on the detector) and the width of the line windows is 10 pixels for all windows. The slit has been moved parallel to itself with 2 arcsec stepsize, and 120 individual spectra were recorded as illustrated in Figure 4. Thus the data file contains 120 individual exposures of each of the line windows and they cover an area of the solar surface of 240×240

4.2 Data format

The SOHO Science Operations Working Group (SOWG) has selected FITS as the standard file format for all the scientific data files generated by the PI teams. The reasons for this are two-fold: First of all, it provides compatibility with existing datasets and software used in the astronomical community, including ground-based solar data. Secondly, it facilitates interoperability between the various instrument teams at the SOHO Experimenters Operation Facility (EOF), since the file structure is independent of computer architecture and operating system. In other words, FITS files looks the same regardless of what computer the file is sitting on, and can be copied from computer to computer without modification.

An analysis of the CDS requirements by William Thompson at GSFC concluded that the best way to store the CDS data in FITS files was to use *binary tables* (Thompson, 1993). We also refer to CDS Software Note No. 3 (Thompson 1993a) for more details about the FITS binary tables. During operations, the science data, as well as associated details about the observations, are extracted from the telemetry files and written to FITS files.

The format of a CDS FITS binary table file as illustrated in Figure 5 can be described as having three parts:

1. The main FITS header. This will describe the observation as a whole. There will be no data array associated with the main header.
2. The FITS header for the binary table. Except for those records peculiar to the FITS structure, this will replicate the information in the main header. It will also describe the columns of the binary table.

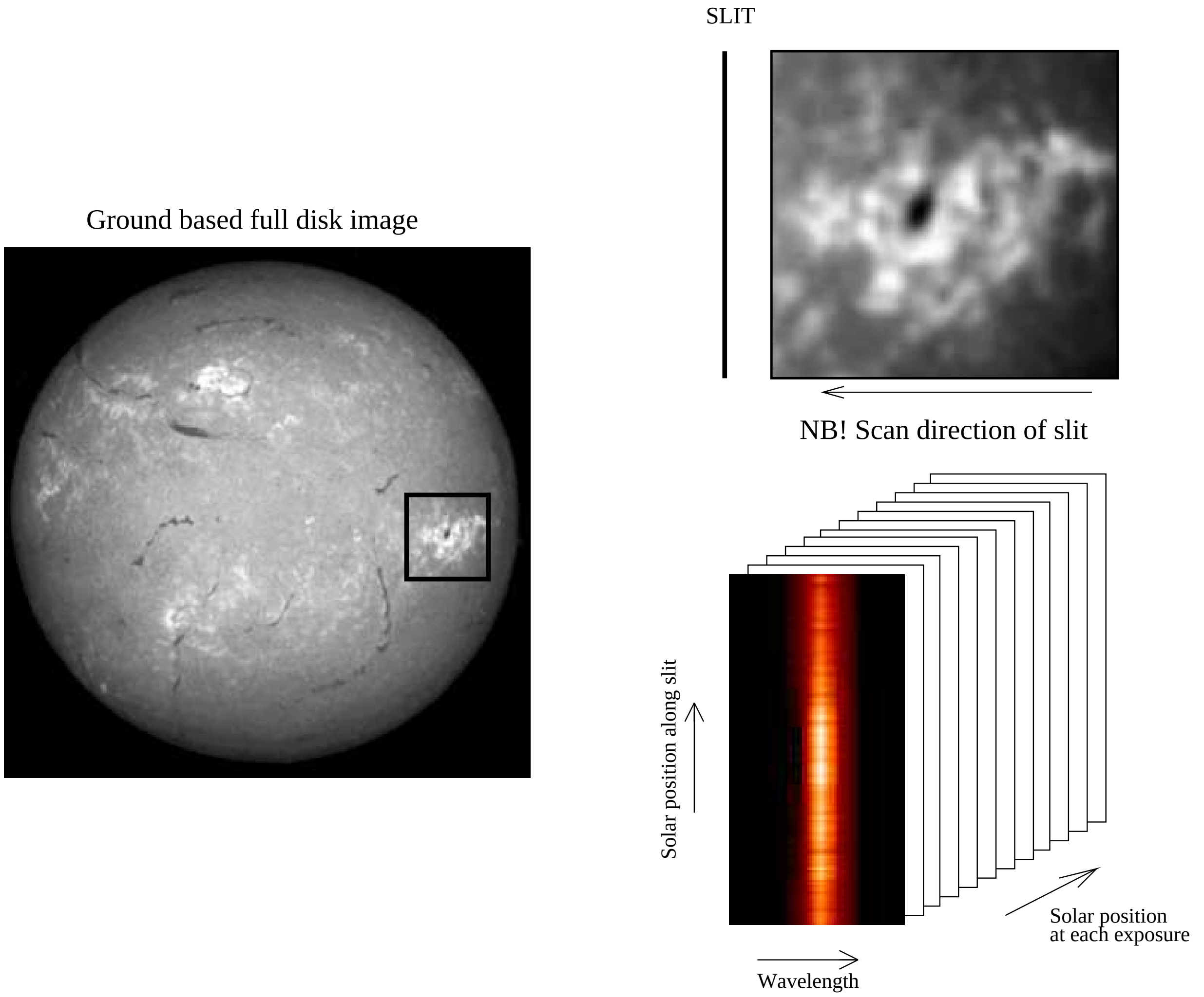


Figure 4: Schematic illustration of an observing sequence with CDS. The 240 arcsec slit was moved in steps of 2 arcsec to cover the marked area of the solar disk. Note that the slit is moved $west \rightarrow\ east$. The exposures are rearranged before the FITS file is created to appear as if they have been taken the other way around. A total of 120 exposures was obtained resulting in a $10 \times 120 \times 120$ data cube for each line window.

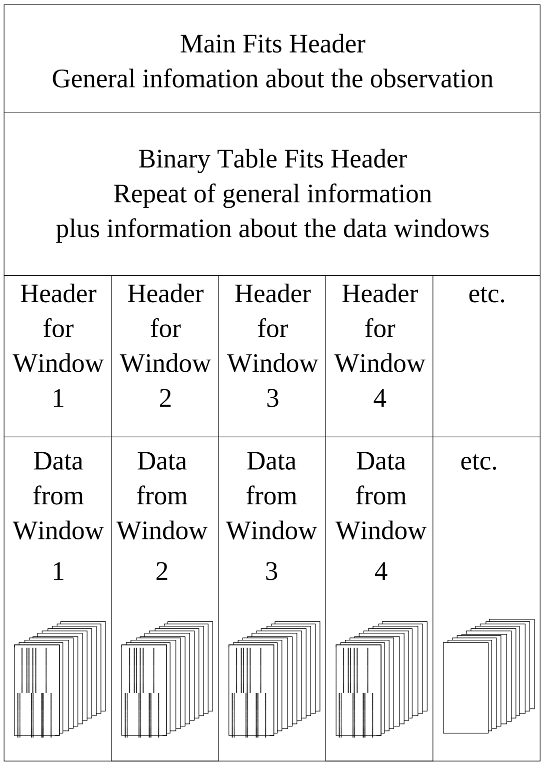


Figure 5: Schematic illustration of the FITS binary table file format. Each data window is stored in a separate column.

3. The body of the binary table. This will contain one complete raster sequence (a series of exposures). Every data window will be stored in a separate column. Additional columns will be used to store data about the individual exposures (e.g. time, pointing, etc.).

If the data on the spacecraft were compressed before transmission, the de-compression will have been applied before the creation of the FITS files. An example of a CDS FITS header with all the keywords is given in Appendix B.

4.3 Data structure in IDL

The Quicklook software for the CDS project is partially menu driven, partially command line driven. To simplify command line operations and construction of specialized analysis software, we felt the need to construct a simple and coherent internal data structure for the data in the FITS files.

To meet these needs, an IDL data structure has been designed to allow all the data in a FITS file to be accessed through a single variable, instead of having, for instance, one variable for each of the detector windows.

The IDL function `READCDSFITS` is used to read a FITS file (e.g., `s3300r00.fits`) into such an IDL structure and is invoked by the statement:

```
IDL> a = readcdsfits('s3300r00')
```

It returns a single anonymous IDL structure variable encompassing all the science data and the auxiliary information that goes with the spectral data in the FITS file. This variable is sent as a parameter to the other Quicklook routines. We have provided routines to "interface" with the data structure. These will return, for instance, the data array corresponding to one particular detector window, or a single spectrum from a given wavelength band. For further information we refer to CDS Software Note No. 9, *CDS IDL Data Structure*, and CDS Software Note No. 41, *Analyzing CDS Data in IDL: An Observers Guide*. In the following the CDS structure returned from `READCDSFITS` is called the Quicklook Data Structure – QLDS. For a discussion of the data structure we refer to CDS Software Note No. 9.

4.4 Specifying Individual Parts of a Raster

Despite the differences between the GIS and the NIS detectors, the data in *any* CDS raster may be viewed as a set of 4-dimensional arrays (one array for each line window). For simplicity, the term "window" is always used, even when "windowing" is not used (full readout).

By convention, the first array dimension is the "dispersion" dimension. The second dimension is the "solar X" dimension, the third is the "solar Y" dimension, and the fourth (when present) is the "time" dimension.

Note that although the nominal solar X/Y dimensions are *usually* aligned with the true solar X/Y directions, this is *not* always the case. Data taken during roll manouvers must be interpreted with care, as the Quicklook software often does not handle these cases properly (resulting in erroneous values for reported solar X/Y coordinates etc.).

To specify parts of the data in a raster, the Quicklook software uses the following terms/keywords:

`WINDOW`, or window index, refers to a specific window in a given raster/QLDS. Windows are referred by numbers (0..NWINDOWS-1).

`OFFSET` refers to the *offset* dispersion pixel within a given line window. The pair `(WINDOW,OFFSET)` uniquely defines a wavelength band and a specific dispersion pixel.

`BAND` is used to refer to a given *wavelength band*, numbered 1 and 2 for NIS, 1 through 4 for GIS.

`DETX` refers to the detector X position. The pair `(BAND,DETX)` has the same function as the pair `(WINDOW,OFFSET)`

`XIX` refers to the X index, i.e., the index of the second dimension of the data array associated with a line window.

`YIX` refers to the Y index, i.e., the index of the third dimension of the data array associated with a line window.

`TIX` refers to the time index, i.e., the index of the fourth dimension of the data array associated with a line window.

5 CDS Quicklook Software

5.1 How to get started

After entering IDL we need to read a FITS file containing science data. If you know the name of the FITS file(s), you may use `READCDSFITS` directly from the IDL prompt (as in Section 4.3 to read in the data.

If you don't know which FITS files you'd like to read in, there are two routines that may be used to browse through lists of observations, `XCAT`, and `PICKFITS`:

Using `XCAT` requires that your system is set up so that `XCAT` can locate the as-run database (see CDS Software Note No. 17).

Using `PICKFITS` requires that you (or someone at your site) use the routine `CFITSLIST` to produce/maintain a list of available FITS files (see the on-line documentation).

Let's assume your're using `XCAT`. Then you'd start by using a command like

```
IDL> xcat,q
```

where `q` is the output parameter, to receive the QLDS.

Select a line with a the desired study, and then select from the rasters in that study. You then select [`Read and Exit with QL data structure`] from the pulldown menu called [`Read & View Current FITS File`]. This will read in the FITS file and exit from XCAT, and the variable `q` will contain the Quicklook Data Structure (QLDS), with the data from the selected fits file.

You may also start the Quicklook "Display Menu" directly from `XCAT` by selecting [`Quicklook`] from the [`Read & View Current FITS File`] pulldown menu. You may even read several rasters after each other, and have one Quicklook Display Menu for each of them. You may exit `XCAT` without killing the Quicklook Display Menus.

NOTE: To enable `XCAT` and the Quicklook Display Menu to be functioning side by side, allowing *several* files to be read and displayed on screen simultaneously, it is impossible[1] to make the data

[1] well, *virtually* impossible

return through the output parameter q. When terminating the Display Menus spawned by XCAT you have two exit options, Exit and DELETE from memory (free space), and Exit and KEEP in memory (recoverable). If you select the first option, the QLDS containing data from that FITS file will be deleted, freeing the memory allocated to it. If you select the KEEP option, however, the QLDS will be kept inside the Quicklook memory management system. When you get back to the IDL prompt (after exiting XCAT), you should use the command @recover to recover the data. This will return the data structures into global variables a, b, c, d, .. etc (never overwriting any *defined* variables you may have, though), telling you where the data ends up.

5.2 Reading selected line windows only

The amount of data in a FITS file is in practice determined by the number of line windows, the size of the windows, and the number of exposures in the raster sequence. When using READCDSFITS from the IDL prompt a set of keywords is available to retrieve only selected parts of the data set or to automatically read only the data that fits below a certain memory limit. The following keywords are valid:

```
/HEADER    ; read only header information -- no data will be loaded
/SELECT    ; prompts for selection of selected detector data windows
PRESELECT ; list of windows to be read in
MEMLIMIT   ; set to maximum size of memory the data are allowed to occupy
/AUTO      ; reading just those data windows that fit below the memory limit
```

Thus, to read only a selection of the line windows use:

```
IDL> a = readcdsfits('s3300r00',/select)
```

For each single line window the program will ask the user if the window should be loaded into IDL.

When using READCSFITS from a user-written program designed to analyze data from only a few (of many) line windows, a lot of time and memory can be saved by using the PRESELECT keyword, e.g.,

```
PRO my_analysis

    files = ['s5500r00','s5500r01','s5500r02','s5500r03','s5500r04']

    for i = 0, n_elements(files)-1 do begin
        qlds = readcdsfits(files(i),preselect = [0,2]) ;; Pick windows 0 and 2

        <process data from this file>

        delete_qlds,qlds ;; Delete it when you don't need it anymore....
    endfor
END
```

5.3 Running QL software from the Display Menu

To start the Display Menu from the IDL prompt after reading in a FITS file, use e.g., IDL> dsp_menu,qlds. This call creates a menu covering the most important features available in the Quicklook software (Figure 8). The available options vary slightly depending on the type of raster.

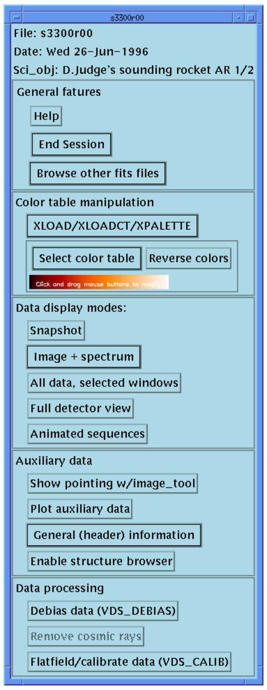


Figure 6: The Display Menu for selection of display modes

In this mode the user does not need to know anything about the names of different routines. However, the different display routines may be called directly from the IDL prompts without calling DSP_MENU first. Examples of how to do this will be given under the description of each display mode and are also listed at the end of the section.

We will now go through the various options in the Display Menu.

5.3.1 General features

[Help]
: This option starts a help widget with information on the various options in the Display Menu. The help text is mostly a repetition of the contents of this software note. Select topics from the left hand list.

[End Session]
: When the Display Menu is started from the IDL prompt, this pulldown menu has only one option, Quit Display menu, which will terminate the menu (and applications started from the menu) and return you to the IDL prompt (unless you have other widget programs running, of course).

If the Display Menu has been started from XCAT or PICKFITS, there is an option to Exit and DELETE from memory (free space), or Exit and KEEP in memory (recoverable). See Section 5.1 for an explanation of these options.

[Browse other fits files]
: You may use this menu to start XCAT or PICKFITS from a Display Menu, to inspect other FITS files without having to terminate all the running widget programs.

5.3.2 Color table manipulation

[XLOAD/XLOADCT/XPALETTE]

Use this menu to start color table manipulation programs. If you do not require extraordinary control over the color table, however, we recommend using the widgets just below. You may select a color table directly from the pulldown menu. You may also adjust the BOTTOM, GAMMA and TOP parameters (as used in XLOADCT) by clicking and dragging the mouse with the left, middle and right buttons inside the color bar area.

5.3.3 Data display modes

[Snapshot]

The snapshot program is a very useful program to produce a quick snapshot of the "what did I get in the field of view" type, written by Bill Thompson. It will also produce hardcopies of what you get on screen. The program has to be run as *modal*, however, so you need to exit from Snapshot before you can do more from the Display Menu. From the IDL prompt: `xcds_snapshot,qlds`.

[Image + spectrum]

This option starts DSP_WAV, a program that displays images of the observed area by taking a slice through the data windows at a given dispersion pixel. You may move around, zoom in/out etc in the image(s). You determine the number of simultaneous data windows to be displayed when selecting from this pulldown menu. It also displays the actual spectrum/line profile from the current point. From the IDL prompt: `dsp_wav,qlds [,nwindows]`.

[All data, selected windows]

This option is very useful for spotting "events" (like sudden changes in intensity/line position etc from one exposure to another) in a dataset. It prompts you to select the line windows to be displayed, and then displays *all* the exposures of those windows in a single draw window. Since the draw window can be very large, it may not work properly without having the DEVICE,RETAIN=2 feature enabled in IDL. For the GIS, single exposures are not images, so instead slit scans (normally north-south) are displayed as images. This program is not as useful with e.g., GIS data, or NIS data taken with a full spectral readout. From the IDL prompt: `dspexp,qlds`.

[Full detector view]

This option starts the program DSPSPEC, which shows the data from the line windows placed at their respective detector positions. For the NIS it shows images of the detector at a given exposure, for the GIS it shows plots of the spectrum acquired at a given exposure.

[Animated sequences]

This option starts DSP_MOVIE, a program originally designed to view NIS wide-slit observations staring at a single point with many exposures. This is still the main purpose of the program, but as long as you have a raster containing 3-dimensional data, it's possible to make animated sequences of various types, which is sometimes nice to highlight certain features in the observations. From the IDL prompt: `dsp_movie,qlds`

5.3.4 Auxiliary data

[Show pointing w/image_tool]
: This option starts the program DSP_POINT, which starts IMAGE_TOOL, passing on pointing information from the FITS header. This enables you to get an overview of the position where the observations were taken. From the IDL prompt: `dsp_point,qlds`

[Plot auxiliary data]
: This option starts the program DSP_AUX, where the various auxiliary data such as pointing, time elapsed since start of the raster etc may be plotted. From the IDL prompt: `dsp_aux,qlds`

[General (header) information]
: This menu is used to start DSP_INFO, which shows some of the information available in the QLDS. There are three options to choose from, displaying general information, (line) window information, and auxiliary data information.

[Enable structure browser]
: Pushing this button will make a pulldown menu called `Structure Browser` appear below it on the Display Menu, and then the `Enable structure browser` button will disappear. The `Structure Browser` works the same way as XPL_STRUCT (see Section 2.2). It is disabled initially to speed up the creation of the Display Menu.

5.3.5 Data processing

[Debias data (VDS_DEBIAS)]
: This option is of course only available for NIS data. It will subtract the bias from the NIS data, but only if the raster includes readout of the background windows.

[Remove cosmic rays]
: This option (available soon) starts XCDS_COSMIC, a program allowing you to select various methods of removing cosmic rays.

[Flatfield/calibrate data (VDS_CALIB)]
: This option calls VDS_CALIB to apply flatfield corrections etc to the data. See `XDOC,'vds_calib'` for details.

5.3.6 When the QL Software crashes

If a QL display routine crashes, the widgets may remain but no interaction is possible and all control is returned to the IDL prompt. In cases like this it is sometimes possible to continue as if nothing happened by typing

```
IDL> retall
IDL> xmanager
```

This is often be sufficient to restart the the xmanager and the widgets become active again.

Sometimes, however, the software keeps on crashing. Killing all the widgets manually, and returning to the main level IDL prompt will normally cause any QLDS supplied to a Quicklook program to appear lost. The data are, however, still stored inside the Quicklook data management system. To recover the data after a crash, do as follows:

```
IDL> q = readcdsfits('testdata3.fits')  ; Read fits file into structure q
IDL> dspspec, q          ; Call DSPSPEC

 --- Assume the session crashed here for some reason ---

IDL> retall
IDL> xmanager

 --- Crashing continues...

IDL> @recover             ; Looks for all possible stored QLDS's
```

On the screen you will see the following output:

```
     This is the QuickLook recovery procedure

     A QLDS has been found, placing it in the global variable 'a'
     % Compiled module: QLDS_FETCH.
     QuickLook recovery finished
     One data structure was found and recovered
```

The data structure has been restored (but note that it's now called a instead of q and you can continue working on the data.

5.4 Data display modes

We will now describe a few of the features available in some of the display programs.

5.4.1 Image + spectrum

This program displays both spatial images and individual spectra. The images are formed by taking a slice through the line window data arrays at a given dispersion pixel index (corresponding to a specific wavelength, hence the name "wavelength slice", or "dsp_wav"). The images thus represent pseudo-monochromatic images.

Of course, this program is not available for rasters without multiple X and Y positions.

To the upper left in the widget, two sections with three pulldown menus illustrate what happens when you use the mouse buttons inside the windows showing the images or spectra.

You may zoom in and out of the images by clicking the right and left mouse buttons respectively. Likewise you may zoom in and out of the spectral plots by clicking the same buttons.

The part of the widget that displays data is divided into in columns, one column displays data from one line window. You may select the line window to be displayed in each column by choosing from the pulldown menu labeled [Window:<window-name>].

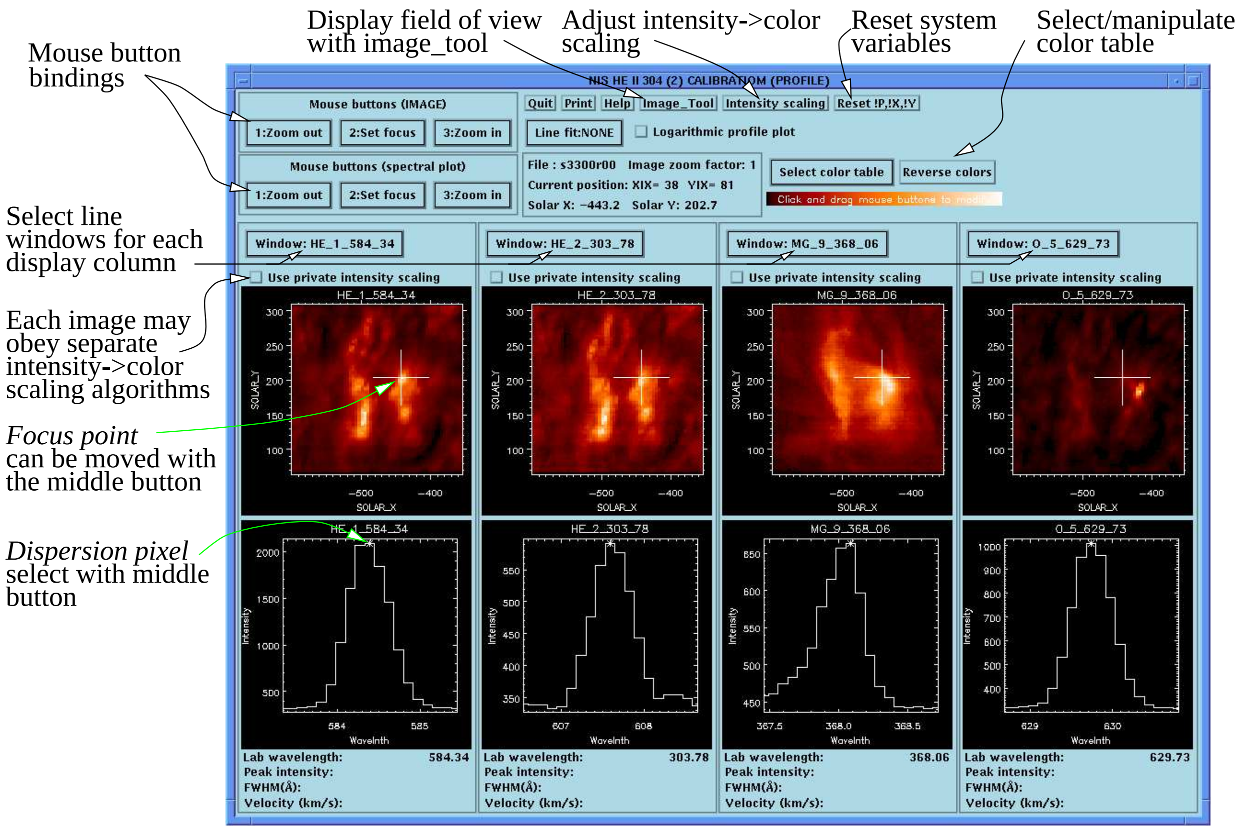


Figure 7: Layout of the Image + spectrum widget

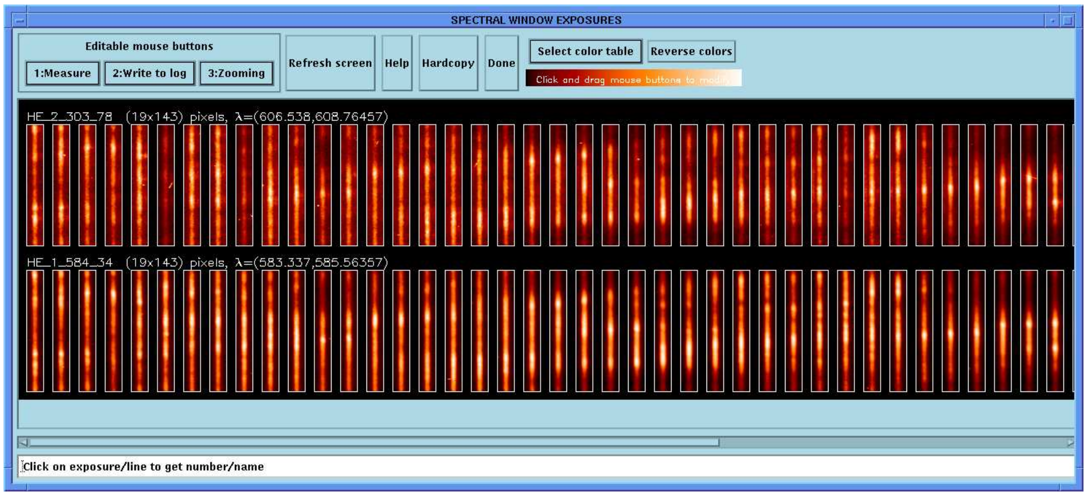


Figure 8: Layout of the "All data, selected windows" program, showing all the NIS exposures in a data set

The spectra/line profiles, shown below the images in each column, are taken from the physical point highlighted by a cross (the *focus point*) in the images. You may move the focus point by clicking the middle mouse button inside the displayed image, and the spectral plot will be updated.

To select the dispersion pixel used to extract the image (highlighted in the spectral plot by an asterisk), you may click the middle mouse button inside the spectral plot. The corresponding image will be updated to reflect the intensities at this dispersion pixel.

Some time in the future, features to display images formed by integration over a specified wavelength band are foreseen. Also, a feature to display spectra averaged over a spatial region of the image has been planned, but not yet implemented.

To exit this application, press the [`Quit`] button. To produce a harcopy, press [`Print`], to display a help text press [`Help`]. To adjust the method used to scale image intensities into color values, press [`Intensity scaling`]. Some times, other programs alter the system variables `!P`, `!X` and `!Y`, causing a garbled display. Press [`Reset !P, !X, !Y`] to correct this.

You can select simple line fits, calculated with various methods by selecting from the menu [`Line fit:NONE`]. The button [`Image_Tool`] shows the field of view of this raster by passing on the coordinates to the program `IMAGE_TOOL`.

5.4.2 All data, selected windows

This program displays all NIS exposures of selected line windows as images side by side. Since a GIS exposure is not an image, all scans (normally north–south) with the slit in a raster will be shown as images. The exposures are spread out one after another in a single window.

The user will first be asked to select a set of line windows to be displayed. A maximum of four line windows can be selected for display. Press *Continue* when satishfied with your selection.

To refresh the display (could be necessary if you haven't specified the `DEVICE,retain=2` backing store) press [`Refresh screen`]. To see a help text, press [`Help`]. The hardcopy option is not implemented yet, so pressing [Hardcopy] simply pops up a message to that effect. To exit the application, press [Done]

The actions of the mouse buttons are once again displayed and controlled by three widget pulldown menus in the upper left corner of the widget. The available options are:

`Measuring intensities/positions`
: Use a mouse button tied to this action to measure the current cursor position and the corresponding wavelength, intensity, exposure number etc. The values are displayed in the status line at the bottom.

`Write last measurements to log`
: Write measured quantities (the information displayed in the status line) to the CDSLOG, an editable text widget. The contents of the log may be saved to a log file.

`Zooming in on part of the display`
: Displays a zoomed image from the selected exposure. New areas can be selected by moving the cursor and clicking the button again. Zoom in and out by clicking the right/left mouse buttons inside the zoom window. More details can be found in Section 5.5.

`Plot int/vel/fwhm`
: This option produces calculates line fits of a *single* Gaussian at each position along the slit, and plots the resulting intensity, velocity and line width in a separate window. The rest wavelength is taken from the *name* of the line window. Note that the results should only be taken as a very rough estimate. Various types of line fitting are available. The descriptions ending with `:PS` has the possibility of making a postscript plot of the results.

5.4.3 Full detector view (NIS version)

This program (`DSPSPEC`) shows the full NIS spectrum for a given exposure, as an image, with the data from the line windows put into their proper positions along the detector X axis. You may move around in the raster inspecting different exposures by moving the slider called `XIX` (or `TIX` for a time-series raster).

To pop up a widget displaying a help text, press [Help]. To exit the application, press [Exit], to produce a hardcopy, press [Hardcopy], to display the field of view of this raster on top of a solar image, press [Image_Tool].

To modify the color table used to display the data, use the [Select color table] menu, the [Reverse colors] button or click and drag the mouse buttons on the color bar to control the TOP, GAMMA and BOTTOM parameters.

The effect of pressing any of the mouse buttons is shown by the text on a series of 3 pulldown menus under the heading `Editable mouse buttons`, in the top left corner of the window.

To change the action tied to a given mouse button, select a new action from the corresponding pulldown menu. The label of the button will be updated. The available actions are:

`Measuring intensities/positions`
: Use a mouse button tied to this action to measure the current cursor position and the corresponding wavelength, intensity, exposure number etc. The values are displayed in the status line.

`Write last measurements to log`
: Write measured quantities (the information displayed in the status line) to the CDSLOG, and editable text widget. The contents of the log may be saved to a log file.

`Zooming in on part of the display`
: Display a zoomed image of a selected region of the displayed spectrum. New areas can be selected by moving the cursor and clicking the button again. Zoom in and out by clicking the right/left mouse buttons inside the zoom window. More details can be found in Section 5.5.

`Drawing profiles from the display`
: Extract and plot profiles (horizontal or vertical) from the displayed spectrum. New areas can be selected by moving the cursor and clicking the button again. The width and the height of the selected area are controlled by widget sliders. The output can be saved to a postscript file or printed directly to a printer. See also Section 5.5.

`Identification of lines`
: Line identification is possible using the extensive line list published by Kelly (1987). By pointing at selected lines the information from Kelly, such as laboratory wavelengths, element, energy levels, and configuration are displayed. The "unreadable" atomic configuration listed in the electronic version of Kelly is decoded into the standard format used in the printed version. The routine `pick_line` can be used to access the Kelly line list in command mode.

5.4.4 Full detector view (GIS version)

This program (`DSPSPEC`) shows the full GIS spectrum for a given exposure as four plots, with the data from the line windows put into their proper positions along the detector. You may move around in the raster by moving the sliders called `X index` and `Y index` (or possibly `Time index` for a time-series raster).

To pop up a widget displaying a help text, press [`Help`]. To exit this application, press [`Done`], to produce a hardcopy, press [`PostScript`]. To view only one of the four detectors, select from the pulldown menu called [`Display detector:...`]. To switch between observed/dummy spectra, select from the [`Observed/Dummy`] pulldown menu.

The mouse buttons do essentially the same things as the mouse buttons do in the NIS version of this program, except the options are all tied to the left mouse button. And, some of the options in the NIS version are not available.

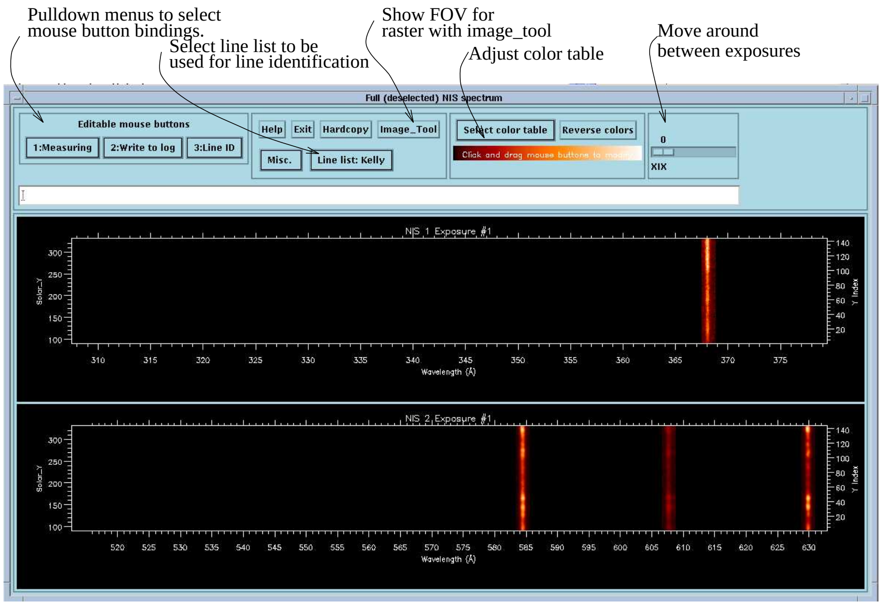


Figure 9: Layout of the `Full detector view` for NIS, showing the entire spectral range.

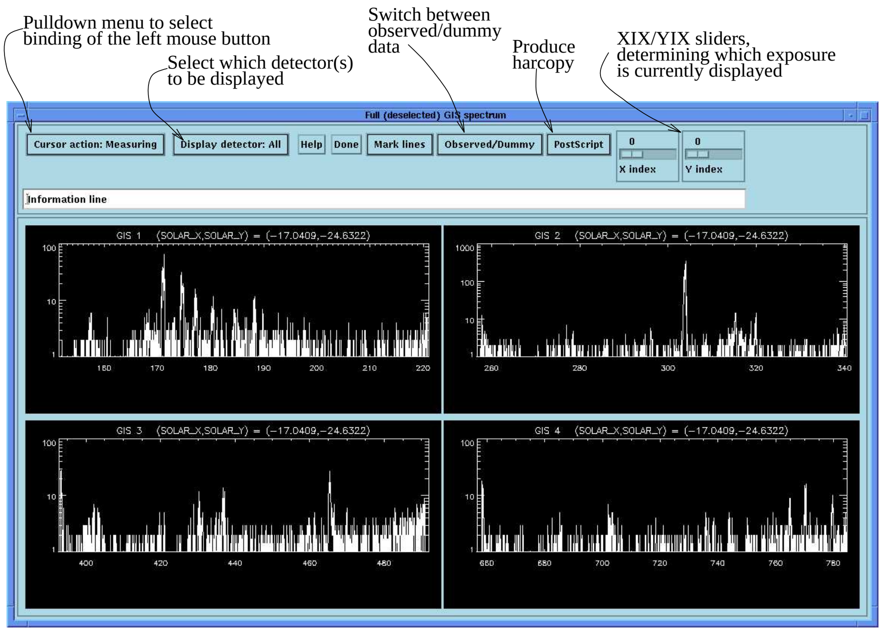


Figure 10: Layout of the `Full detector view` for GIS, showing the entire spectral range.

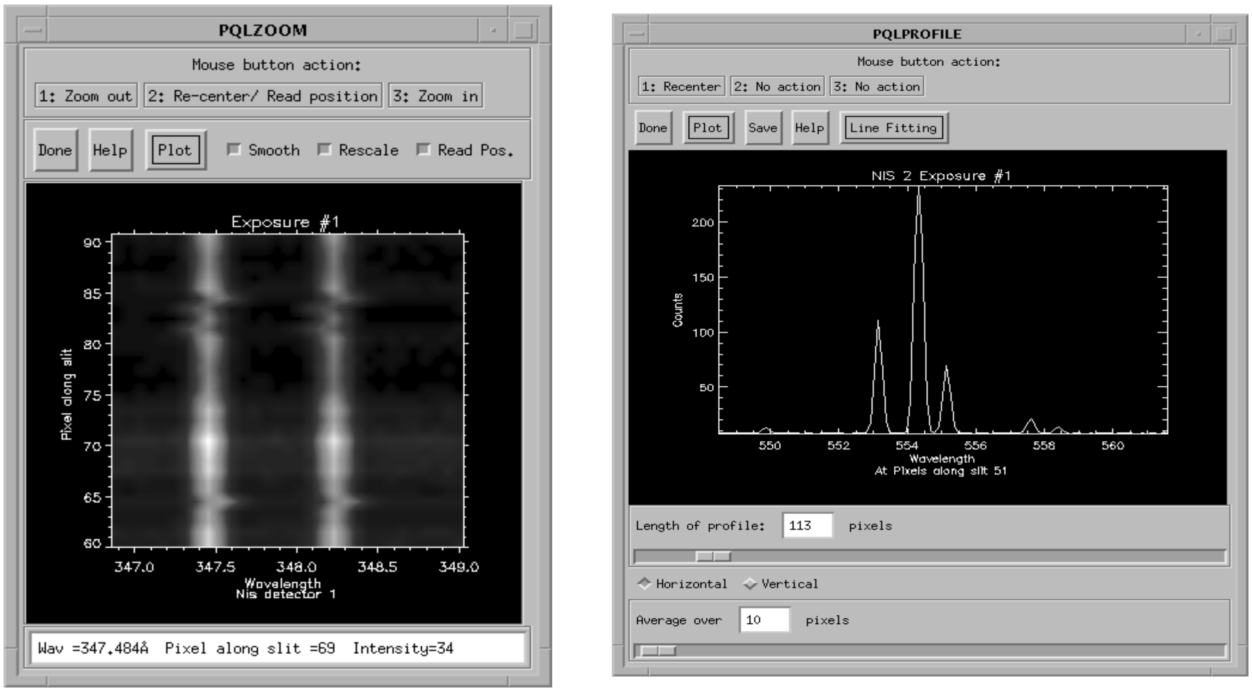


Figure 11: Layout of the Zoom and Profile utilities.

5.5 Zooming and Profiling utilities

5.5.1 Zoom utility

A general zoom routine has been developed and may be used from some of the main display modules. From the displays of [`Full detector view`] (DSPSPEC) for the NIS and [`All data, selected windows`] (DSPEXP) the zoom routine is selected by choosing the zoom function for one of the mouse buttons, and then clicking that mouse button in a region of interest. The layout of the zoom widget is shown in Figure 11.

To select another area of interest, move the cursor in the original window and press the mouse button again.

You can zoom in/out by using the right/left mouse buttons, and recenter the display by using the middle button.

To measure intensities/positions inside the zoom window, select that option for one of the mouse buttons and click in the zoom window.

5.5.2 Profile utility

A profile routine can be envoked from the `Full detector view` (DSPSPEC) and the `All data, selected windows` (DSPEXP) display modes. Select the profiling option on one of the mouse buttons, and click inside a display window in a region of interest. The layout of the profile widget is shown in Figure 11.

To show a profile from another position, move the cursor in the original window and press the mouse button again.

When plotting profiles from an image, you may switch between a horizontal and vertical mode.

To zoom in and out of the profile plot, use the right/left mouse buttons.

You may average the profiles over several lines by moving the slider at the bottom of the profile widget.

5.6 Inspecting CDS data in command mode

Many users will probably like to work with CDS data interactively from the IDL prompt (command mode). This section demonstrates just a few of the routines available to extract data from the data structures and display them, by providing an "example session". For more detailed information on the data extraction routines, we refer to CDS Software Note No. 41. Since most of the data extraction routines start with "gt_", another tip is to use `IDL> tftd,'gt_'` and see what comes out.

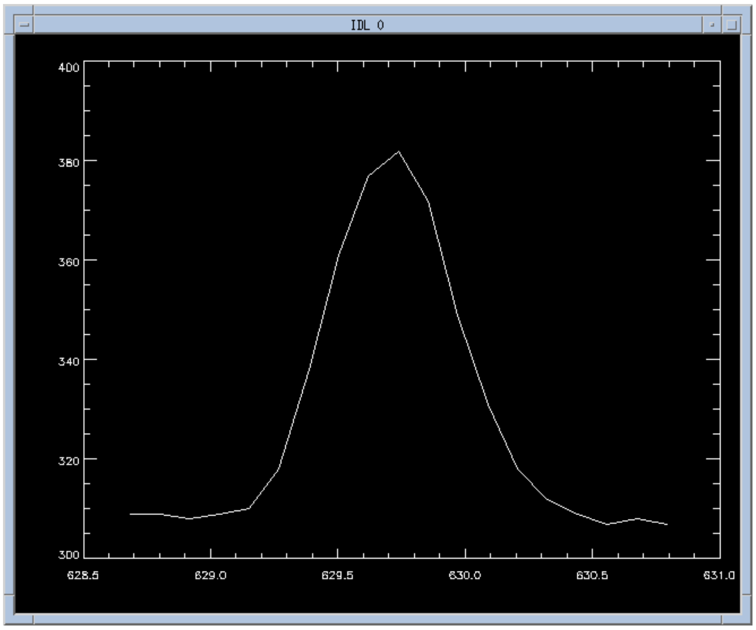
First, we read in the data and find out a little bit about what we have:

```
IDL> a=readcdsfits("s3300r00")
IDL> print,gt_wlimits(a)          ; What kind of windows do we have

       Window:       0             Label: HE_1_584_34
       Band:         NIS2
       Det-X:              602         to      620
       Det-Y:              336         to      478
       Wavelength:          583.33722    to       585.44635

       Window:       1             Label: HE_2_303_78
       Band:         NIS2
       Det-X:              800         to      818
       Det-Y:              338         to      480
       Wavelength:          606.53755    to       608.64667

       Window:       2             Label: MG_9_368_06
       Band:         NIS1
       Det-X:              854         to      872
       Det-Y:              586         to      728
       Wavelength:          367.45407    to       368.71681

       Window:       3             Label: O_5_629_73
       Band:         NIS2
       Det-X:              989         to     1007
       Det-Y:              340         to      482
       Wavelength:          628.68332    to       630.79244
     602     620     336     478
     800     818     338     480
     854     872     586     728
     989    1007     340     482
IDL> dim = gt_dimension(a)     ; What data dimensions are present, and
IDL> help,dim,/str             ; what sizes do they have?
** Structure QL_DIMENSION, 17 tags, length=152:
   WAVELNTH        BYTE         1
   SWAVELNTH       LONG                19
   SOLAR_X         BYTE         1
   SSOLAR_X        LONG                60
   SOLAR_Y         BYTE         1
   SSOLAR_Y        LONG               143
```

```
   DEL_TIME        BYTE         0
   SDEL_TIME       INT              0
   WAVELNTH_ORIGIN DOUBLE    Array(4)
   WAVELNTH_SPACINGDOUBLE    Array(4)
   SOLAR_X_ORIGIN  DOUBLE          -597.58600
   SOLAR_X_SPACING DOUBLE           4.0640000
   SOLAR_Y_ORIGIN  DOUBLE           66.662500
   SOLAR_Y_SPACING DOUBLE           1.6800000
   DEL_TIME_ORIGIN FLOAT           0.00000
   DEL_TIME_SPACINGDOUBLE           10.000000
   NDIMS           INT              3
IDL>
```

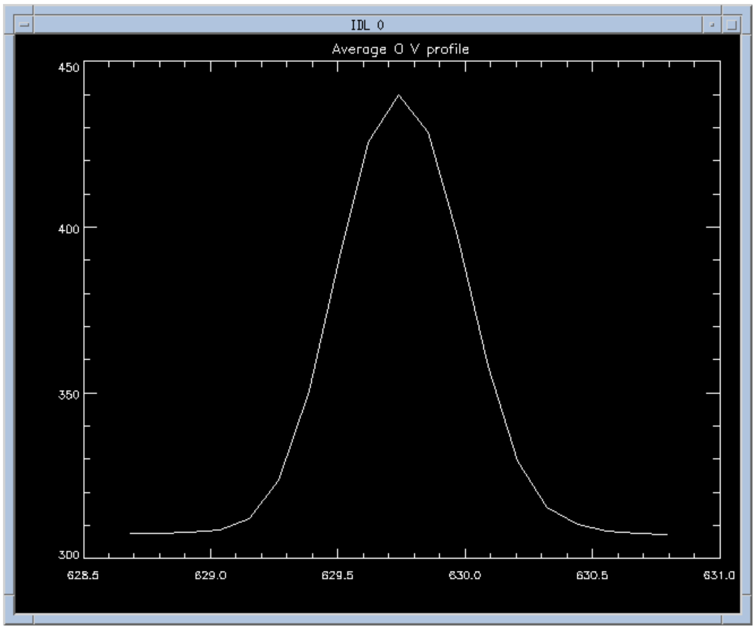
I.e., we have four windows, and the line windows have dimensions (19,60,143). Let's say we'd like to have a look at the O V window – first we'll extract a spectrum from the middle of the raster:

```
IDL> spec=gt_spectrum(a,window=3,xix=30,yix=70,lambda=lam)
IDL> window,0
IDL> plot,lam,spec,/ynozero ; lambda returns the wavelength array
```



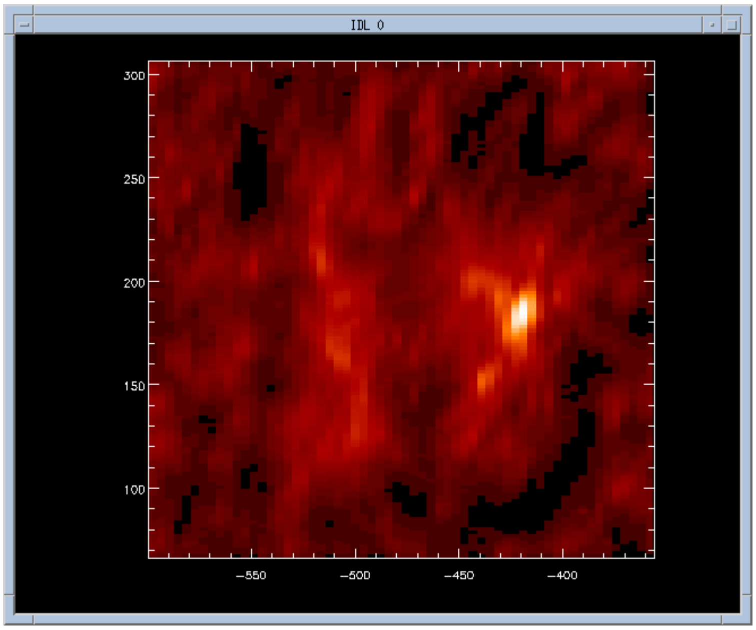
And if we want to get the spectrum averaged over the whole raster:

```
IDL> data=gt_windata(a,3) ;; Returns the whole data array for this window
IDL> help,data
DATA            FLOAT     = Array(19, 60, 143)
IDL> ; Successive averaging over both spatial dimensions
IDL> plot,lam,average(average(data,2),2),title='Average O V profile',/ynozero
```



Now, we'll extract an image by integrating over a wavelength band:

```
IDL> im = gt_bimage(a,629.2,630.5)
IDL> origin=[dim.solar_x_origin,dim.solar_y_origin]  ; Make sure we get
IDL> scale=[dim.solar_x_spacing,dim.solar_y_spacing] ; coordinates etc. right
IDL> plot_image,im,origin=origin,scale=scale
IDL> loadct,3
IDL> gamma_ct,.3       ; Get a reasonable color table
```



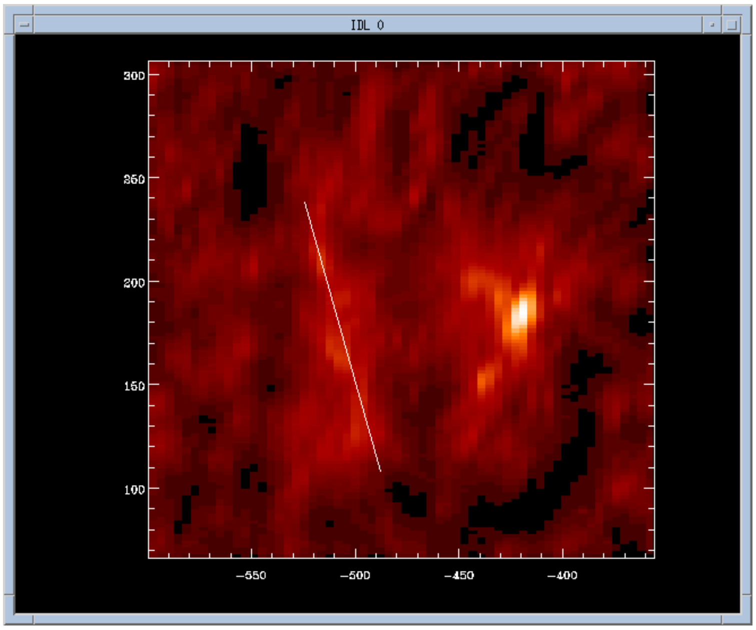
To view profiles (horizontal or vertical) profiles from this image, use

```
IDL> tvprofile,im
```

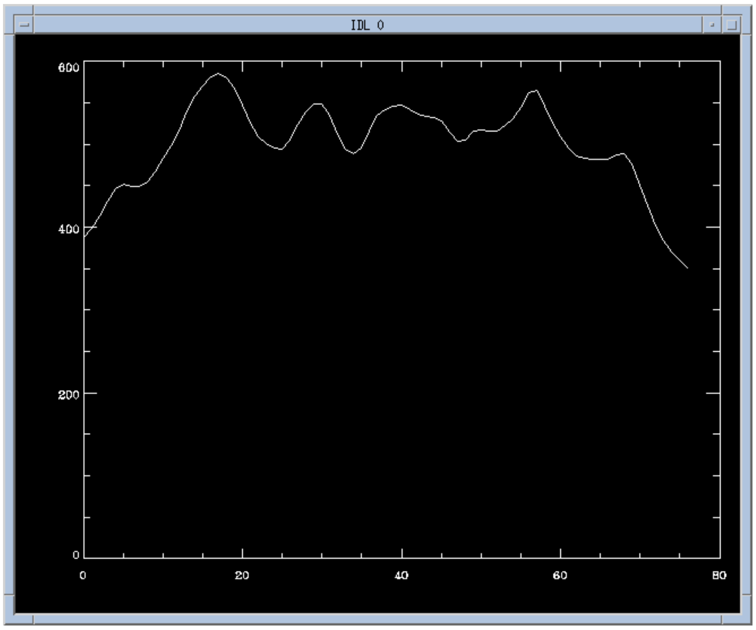
A window pops up to display the profiles. Move the mouse inside the displayed image. Click the left button to switch between horizontal/vertical, press the right button to exit.

Another very useful routine is TVPROF to extract a profile along a user defined path. The user is prompted to enter (using the cursor, left button) a series of points defining the path to take the profile along. The procedure is completed by clicking the right mouse button.

```
IDL> tvprof, image, profile, xval, yval   ; To extract profile along a path
```




```
IDL> plot, profile                        ; Plot profile
```



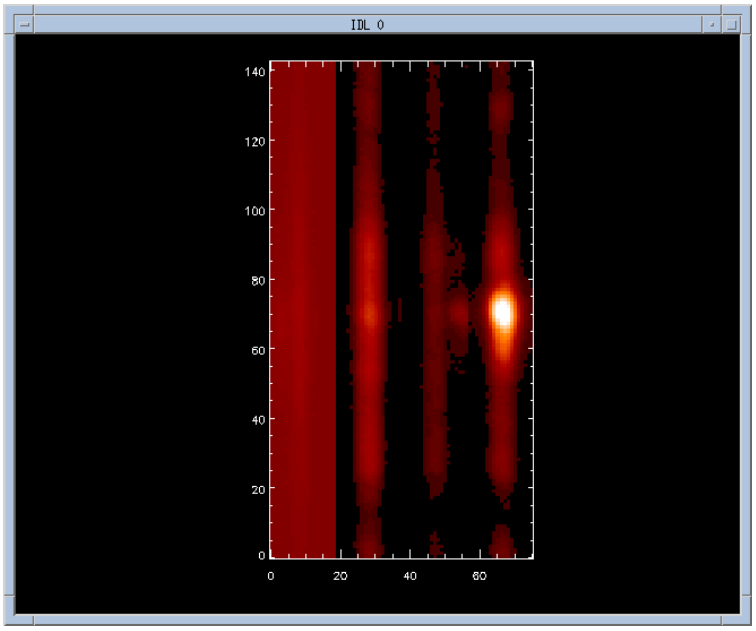
The routine TVVALUE can be used to extract values of a displayed image interactively:

```
IDL> tvvalue, image
```

A widget pops up displaying the pixel x/y coordinates, and the pixel value of the pixel under the mouse cursor. The left or center mouse buttons prints out the value, the right button exits.

To e.g., get a slit spectrogram through (with the data from all the line windows) through the bright spot in the image:

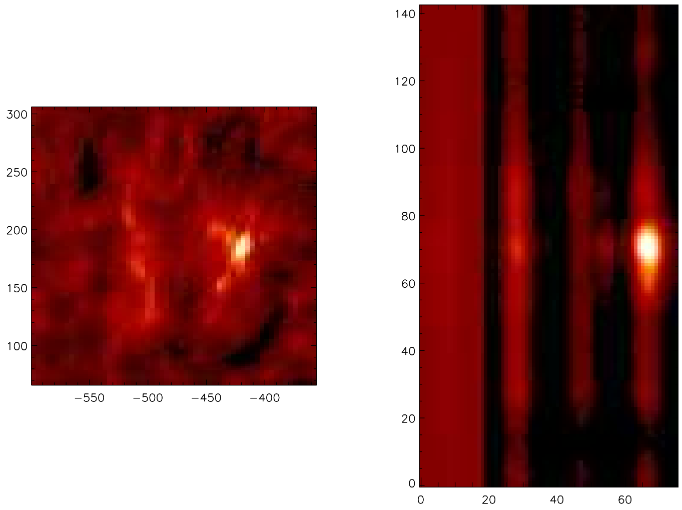
```
IDL> scan=gt_scany(a,window=[0,1,2,3],xix=44)
IDL> plot_image,scan
```



If you would like to make postscript output, this is easily accomplished:

```
IDL> ps,'psdemo.ps',/color,/copy  ; Copy color table
IDL> !P.multi=[0,2,1]
IDL> plot_image,im,origin=origin,scale=scale
IDL> plot_image,scan
IDL> psclose
```

This produces the following output in the postscript file:



For more details and examples about using the SERTS software we refer to CDS Software Notes No. 5 and 6.

5.7 Other useful stuff

PICK_LINE() Extract laboratory data of line from Kelly's line list

Kelly's line list (or part of it) is searched, and a display pops up with the lines that were within a range around the given wavelength (default +/- 0.5 Angstrom). The information from Kelly, such as laboratory wavelengths, element, energy levels, and configuration are displayed. The "unreadable" atomic configuration listed in the electronic version of Kelly is decoded into the standard format used in the printed version.

```
IDL> dum=pick_line(lambda)           ; General use
IDL> dum=pick_line(600.5)            ; List lines between 600.0 - 601.0 A
IDL> dum=pick_line(600.5,delta=0.1)  ; List lines between 600.4 - 600.6 A
```

6 Analysis of CDS data, line fitting.

The latest (and possibly last) addition to the CDS QL software is a set of programs designed to allow easy analysis of the data through line fitting. The system uses the Component Fitting (CFIT) System (see CDS Software Note No. 47) as the central "engine".

CFIT routines have a point-and-click interface allowing any number of e.g., Gaussian components to be included in one fit model, and then applying this model to a block of data, either in batch mode or interactively, and then inspecting, tweaking and "patching" the result to cope with difficult data sets.

As a "bridge" between the CFIT procedures and CDS QL software, the concept of an "analysis definition" (ADEF) has been made.

An ADEF describes most of the steps that are necessary from the identification of a data set (i.e., the name of the fits file), to the final result, unless "unusual" requirements are made.

6.1 A working example: From QLDS to velocity map

First, read in some data and start DSP_MENU

```
IDL> a = readcdsfits("s9293r04") ; a {\tt SYNOP\_F} raster at sun center
IDL> dsp_menu,a
```

Press [XCDS_ANALYSIS] (at the bottom of the display menu), and the XCDS_ANALYSIS widget appears. Select the O V data window from the pulldown menu [Current window: ...], then press [Add this window]. The list of windows is updated to show the following for the added window:

Index: This is the window index.

Label: The window label, taken from the QLDS, but you may edit it if you like. Useful when analyzing e.g., parts of a full-spectrum observation (e.g., NISAT_S) using the Crop facility.

GR_ORDER: Grating order – if you'd like the wavelength array associated with a window to match the physical wavelength of a second order line, you may press this button to switch between first and second order.

Crop: If you'd like to extract only parts of a data window, press this button to start XCDS_CROP, which allows you to define the part to be extracted.

Current size: When using the Crop facility with several windows, it's important that all windows are cropped to the same size in the physical (not wavelength) dimensions.

Delete: To remove a window from the window list, press this.

Now, select [File] : [Save as], and determine where the analysis definition should be saved. (Note that the "Pattern for analysis file names" is defined in terms of the name, path and contents of the analysis definition).

Then, press [Apply analysis definition] : [Generate ...]. The current ADEF will be applied to the current QLDS (by the program APPLY_CDS_ADEF). This includes looking for a file with a list of missing pixels and, assuming that it doesn't find one, executing CDS_CLEAN_EXP as a last resort. It is thus possible to keep files with lists of missing pixels (from manual verification of the automatic cosmic ray removal routines) that will be taken into account automatically.

Then the data window is extracted from the QLDS after performing various calibrations. Weights and wavelength arrays are generated, and everything is inserted into an *analysis structure* and passed on to XCFIT_BLOCK. The calculation of the wavelength array does compensate for the wavelength tilt (see MK_CDS_ANALYSIS).

Since our ADEF does not yet contain any fit model, the model that is fitted to the data only contains a zero-order polynomial. Now, select [Redesign] : [Discard ... redesign fit structure], and the XCFIT program starts. Select [Add component...] : [..showing absolute position], and a Gaussian is added to the model. The initial values are guessed in a rather crude way. Press [Redo fit], then [Use as initial state] : [(value -> initial)], then [Exit] : [Save changes].

Now, select [Calculate] : [...from global initial values]. It takes a while, but when the calculation is finished, you may select [Result:..] : [gauss] : [Position], and the middle column will now show the "velocity" map (actually, the *line position* map).

To save the analysis, select [File/exit] : [Save], and it will be saved in the file indicated by the pattern given in the analysis definition. That's it, basically.

Now, exit from XCFIT_BLOCK and XCDS_ANALYSIS (make sure you save the ADEF again on the way out - since the fit structure is now changed and should be saved), then exit from DSP_MENU.

6.2 Starting from the prompt

To recover the analysis definition at the IDL prompt, use e.g.,

```
IDL> adef = restore_cds_adef()
```

and pick the file name that you used to save the analysis definition. Start XCDS_ANALYSIS again from the IDL prompt, with

```
IDL> xcds_analysis,adef,analysis,qlds=a
```

Now, if you press [Load analysis], the analysis you just saved will be loaded automatically (since the pattern for analysis file names provides a unique file name, given the QLDS). When you exit from XCDS_ANALYSIS, analysis will contain the currently loaded analysis.

You may start XCDS_ANALYSIS from the prompt without supplying any QLDS, in which case you're not allowed to edit the ADEF, and, since the analysis file name cannot be determined uniquely, you'll have to select between any existing analyses matching the ADEF.

You may also start XCDS_ANALYSIS from the prompt without supplying any defined ADEF parameter, but in that case the QLDS must be supplied.

6.3 Useful stuff

There are too many details concerning XCDS_ANALYSIS (and the programs that it relies on) to explain here, but do have a look at the online help for the following functions:

SAVE_CDS_ADEF, RESTORE_CDS_ADEF, DELETE_CDS_ADEF, APPLY_CDS_ADEF, CDS_ADEF_PARSEFILE, MK_CDS_ANALYSIS

Once you have defined an ADEF structure, it may be applied to other data sets with the same raster id/variation, as follows:

```
IDL> ana = apply_cds_adef(adef,'s9293r05')
IDL> cfit_block,analysis=ana,/double
```

This will read in the QLDS (but selecting only the window used by the ADEF), extract the data, calculate weights etc, then the QLDS will be deleted, and an analysis structure will be returned. If you now try to save the analysis structure (with SAVE_ANALYSIS), the name will reflect the fact that the data is taken from a new fits file.

A brief explanation of the ADEF structure (CDS_ADEF_STC) tags is also required. The tags are:

```
FILENAME        STRING - The file name of the ADEF
RAS_ID          LONG   - Raster ID
RAS_VAR         LONG   - Raster Variation
ANA_FILENAME    STRING - Pattern for analysis file names
DEBIAS          BYTE   - Debias onoff     1
COSMIC          STRING - How to handle cosmic rays
FILL_COSMIC     BYTE   - On/off
VDS_CALIB       BYTE   - On/off
NOBURNIN        BYTE   - On/off
USE_COUNTS      BYTE   - On/off
CALIBRATE       BYTE   - On/off
ERGS            BYTE   - On/off
STERADIANS      BYTE   - On/off
ANGSTROMS       BYTE   - On/off
WINDOWS_H       LONG   - Handle - points to window descriptions
FIT_H           LONG   - Handle - points to default fit structure
```

The tag WINDOWS_H points to an array of CDS_ADEF_WINDOW structures with information on each data window to be included, the cropping to be applied etc. The structure contains the following tags:

```
IX              LONG   - The window index
GR_ORDER        INT    - Grating order
LABEL           STRING - Label
CROP            STRUCT - Cropping structure
```

The cropping structure (CDS_ADEF_CROP) cosists of two tags, B (for *begin*) and E (for *end*), and both are LONG arrays with 7 elements. The cropping of any IDL data cube according to such a cropping structure is achieved by:

```
IDL> b = crop.b
IDL> e = crop.e
IDL> cropped_cube = cube(b(0):e(0),b(1):e(1),b(2):e(2),b(3):e(3),$
                         b(4):e(4),b(5):e(5),b(6):e(6))
```

When analyzing full-spectrum NIS data sets (e.g., NISAT_S) and including two or more lines with a considerable distance on the detector in a single analysis, it may be wise to adjust the cropping manually (not just through XCROP_CUBE) to correct for the position tilt of the spectrum.

7 Acknowledgments

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A CDS Software Notes

The CDS software note series is a set of documents specially related to SOHO/CDS software matters. They pertain to all aspects of the software and are gathered together here for ease of reference and access.

Note	Title	Author
00	This index.	
01	CDS ground based software requirements	C D Pike
02	CDS catalog definitions	W Thompson
03	Converting CDS telemetry to FITS files	W Thompson
04	IDL software for FITS binary tables	W Thompson
05	SERTS graphics devices routines	W Thompson
06	SERTS image display routines	W Thompson
07	CDS Planning Tool Users' Guide	D M Zarro & L Wang
08	CDS software and data directories	C D Pike
09	CDS IDL data structure	S V Haugan
10	The UIT IDL database system	W Thompson
11	Converting CDS calibration telemetry to FITS	W Thompson
12	User guide to calibration science analyser	C D Pike
13	Report on VDS subsystem calibration	W Thompson
14	Time conversion routines	W Thompson
15	Study identifications	R A Harrison
16	C Utility programs for IDL programming	S V Haugan
17	Installing the CDS software	C D Pike, W Thompson & D M Zarro
18*	CDS Interoperability software	W Thompson
19	Other SoHO Interoperability software	W Thompson
20*	Quicklook software user manual	P Brekke & S V Haugan
21	Profile fitting to CDS/SUMER data	N Brynildsen
22	CDS on-line help utilities	C D Pike
23	CDS FITS generation software	W Thompson
24	CDS Technical Planning software	C D Pike
25	Command Preparation Software	M K Carter
26	Engineering telemetry monitor (EMON)	C D Pike
27	Guide to the Science Telemetry Monitor (STM)	C D Pike
28	Tape Archiving Procedures for the SoHO/CDS	D Luttermoser
29	CDS Planning Database Directories	C D Pike
30	CDHS State Database Software	M K Carter
31	Monitoring CDS mechanical use	C D Pike
32	A QL Density/Temp. Diagnostic Tool for CDS	P G Judge & P Brekke
33	The CHIANTI Synthetic Spectrum Program for CDS/SUMER	K Dere et al
34	Applying Calibration to VDS Data	W Thompson
35	CDS Temperature Monitoring	C D Pike
36	CDS QCM Monitoring	C D Pike

37	Density and temperature diagnostic Line Ratios for CDS/SUMER using CHIANTI	K Dere et al
38	IDL access to CDS telemetry files	C D Pike
39	Automatic line fitting to CDS spectra	B J Kellett
40	CDS Engineering studies.	M K Carter
41	Analyzing CDS data in IDL: An Observers Guide	S V H Haugan
42	A Guide for the Visiting Scientist	W Thompson
43	Processing CDS Level-0 CDROMs	W Thompson
44	Study Durations	W Thompson
45	CDS Solar Feature Tracking	C D Pike

Addresses

Any comments or suggestions would be appreciated, and can be directed to the authors at the following addresses:

Institute of Theoretical Astrophysics
P.O.Box 1029, Blinder
N-0315 Oslo
NORWAY
Fax No.: (+47) 22 85 65 05

Paal Brekke
Phone: (+47) 22 85 65 08
Internet: paalb@astro.uio.no

Stein Vidar Hagfors Haugan
Phone: (+47) 22 85 65 31
Internet: steinhh@astro.uio.no