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Contents

Introduction

This document describes the data display systems proposed for SCUBA-2 FTS (FTS-2), and is based partly on the display requirements described in SC2/FTS/SRE/001. The FTS-2 display system will follow the conventions for the SCUBA-2 display system, described in SC2/SOF/S210/002: "The display system is entirely data driven via files appearing on disk from the Data Acquisition system and data can only be displayed once the files are closed by the DA system. The key constraint on the display system is that no displays are attached directly to the real-time data stream from the DA computers."

Three display modes will be considered: Pipeline reduced data display, Quick Look reduced data display and Strip-Chart display of instrument diagnostics. The Pipeline display is responsible for displaying properly reduced data. The Quick Look display (QL) displays minimally processed data to the observer as fast as possible (without any analysis or calibration). The Strip-Chart display can be used to plot diagnostic parameters over time, such as the maximum ZPD value, spectral S/N, etc. Each of these systems and details of implementation will be discussed in the subsequent sections.

FTS-2 will be operated in either a low-resolution SED mode or a high-resolution spectral line mode.[1] The SED mode is used for determination of dust emissivity, β, and temperature from the shape of the continuum component in the spectra. This mode can be used with the 850 μm band alone, or with dual-band observations.[2] The spectral line mode will be used for studying line intensities as well as continuum information. See the FTS-2 Science Case (SC2/FTS/SCE/002) for more detail.

Definitions

The following definitions are important for this document:

sample

Data corresponding to a single time-slice in the raw data array (usually sampled at 200 Hz). Implicitly includes all the (40 × 32) bolometers read out at that time.

frame

The smallest data unit manipulated by the Pipeline. Corresponds to a single file on disk with a single FITS header.

interferogram

A sequence of frames forming a complete interferogram data cube resulting from a complete scan of the moving mirror over the required range.

observation

The collection of frames corresponding to a single CONFIGURE in the observation sequencer. For FTS observations, this will correspond to a single interferogram.

group

A collection of related observations that can be combined by the Pipeline. For example, a group can correspond to repeats of identical observations to improve signal-to-noise.

1. Pipeline display

The FTS-2 Pipeline Engine will use the standard ORAC-DR display interface. The ORAC-DR display system has the following properties (SC2/SOF/S210/002):

- The Recipes only include an instruction to display some data, not how they should be displayed.
- The Pipeline user can control which data products they are interested in and how they should be displayed. This can be changed whilst the Pipeline is running.
- A single data product can be displayed in multiple ways without affecting the DR Recipe.
- It is not tied to any particular display engine.
- The display system can be turned off (e.g. during batch processing).

The FTS-2 display system will follow the same scheme as the SCUBA-2 Data Display System:

> "..when the reduction primitive creates some data product that it feels could be useful for display it sends the frame information (this can be a frame or a group object) to the display system. The display system then uses the last component of the file name (filenames use underscores as delimiters) as a key and searches for that key in the display configuration system. The configuration system includes information on how to process each file suffix. This includes the backend display engine to use, the type of display required (spectrum, image, contours etc.), and any additional parameters such as pixel bounds for a sub-region of the image or whether the display should autoscale. Furthermore, if the dimensionality of the file is too high for the requested format (e.g. displaying an image as a spectrum) the file is automatically converted to the correct dimensionality by averaging over the redundant axes. For each entry that matches the supplied key (e.g. mos or reb), the relevant display engine is contacted and the file is displayed in the required manner. The database can be edited at any time whilst ORAC-DR is executing, as it is re-read each time a file is displayed.
> This approach allows the Pipeline to be effectively decoupled from the display system and relieves the Recipe writer from worrying how their products will be displayed."

Offline processing does not have the performance constraints of the online processing, so more thorough processing can be done prior to displaying the data. There are several intermediate steps in the FTS processing that are often useful to inspect in order to verify that the processing is configured properly, such as the results of the phase fitting and phase correction. The details of the offline processing display are TBD at the time of writing, although we will likely implement the same level of inspection capabilities as the U of L FTS and SPIRE pipelines provide.

2. “Quick Look” display

The key requirements for the Quick Look system (from the DR software requirements, repeated here for clarity) are:

- The display should not fall behind observing.
- Data frames should be displayed as quickly as possible to the observer (in a meaningful coordinate system).
- A co-added image for the current observation should be displayed as quickly as possible.
- Images of particular significance, e.g. those generated when an observation is complete and possible DARK frames, will be displayed on a separate window so that they remain visible for longer and so they can be examined interactively by the observer without fear of the image being rapidly replaced.

There is an additional assumption that data displayed by the QL system does not need to be extinction corrected or flux calibrated. This assumes that a single observation does not last for hours, or cover a large range of elevations and opacity. The FTS-2 QL display will fulfill these requirements.

The SCUBA-2 QL display consists of a separate instance of the Data Reduction Pipeline running _QUICK_LOOK variants of the normal Recipes; each Recipe supported by the Pipeline will also have a version optimized for QL. Accordingly, the FTS-2 processing recipes will have QL variants. e.g. FTS2_FFT would have a corresponding FTS2_FFT_QUICK_LOOK.

GAIA is the proposed display tool for SCUBA-2 QL-generated images, and will be used for the FTS-2 QL display as well. Spectral display will be handled by SPLAT.

2.1. Quick Look Recipes

This section describes the FTS-2 data processing steps required to generate the data for the Quick Look display. At the time of writing, the processing code is still being benchmarked and some of the data reduction algorithms are still being developed, so the details of the QL recipes may change depending on the processing budget.

2.1.1. SED mode

The QL display for the SED mode will display 2D images corresponding to the integrated power in both bands, the ratio of the integrated power in both bands, or possibly the slope of the continuum across the band(s). The skeleton of a SED QL recipe could be the following:

1. apply flat-field
2. FT the double-sided interferograms with simplified phase correction
3. Integrate over the specified spectral bandpass

4. Generate an image of the ratio of the integrated power in both bands
5. re-grid the reduced image onto RA/DEC

In the SED mode, scans will be completed before sky rotation becomes significant, so rotation onto Ra/Dec could be done on the final reduced image instead of the individual 200 Hz frames. Further tests are required to determine the processing overhead.

2.1.2. Spectral Line mode

Full processing of high-resolution spectra for the entire FOV is too time consuming for the QL display, so either a single pixel or a region of interest will be specified in the configuration. The QL processing will present a single spectrum to the display system.

1. apply flat-field
2. re-grid frames onto Ra/Dec (if scan time requires it)
3. Interpolate interferogram frames onto uniform OPD grid
4. Phase correct
5. FT / apodize the interferogram(s)
6. Display the spectrum

Although sky rotation will begin to be significant over the duration of a high-resolution scan, it may be acceptable to ignore this for the QL display if the re-gridding is too time consuming.

3. Stripchart display

The SCUBA-2 stripchart utility (SC2/SOF/S210/006) will be used to display time series of instrumental parameters and statistics on the reduced spectra. In addition to the SCUBA-2 parameters normally displayed, the following FTS parameters will be produced by the FTS-2 DR engine and logged for display:

- max/min ZPD value for a given pixel or region of interest
- ZPD location for a given pixel
- integrated power (full bandpass or smaller range) for both bands
- spectral S/N

4. Display packages

Different display systems will be preferred for the QL and offline displays, as well as for displaying the potential 1-D, 2-D and 3-D data. The QL system will provide efficient display of partially reduced data in order to allow the observer to gauge the system performance and observation progress. The offline display, however, will require more sophisticated display tools to display the 3-D spectral cubes.

As far as possible, the FTS-2 software will use existing SCUBA-2 display packages for the pipeline and QL display.

4.1. 1-D display

For displaying 1-D spectra, interferograms and other information, the Starlink Spectral Analysis Tool (SPLAT) will be used. See [Starlink User Note 243.1](#) for more information. SPLAT displays line plots of spectra from various file formats which can be interactively manipulated and analysed.

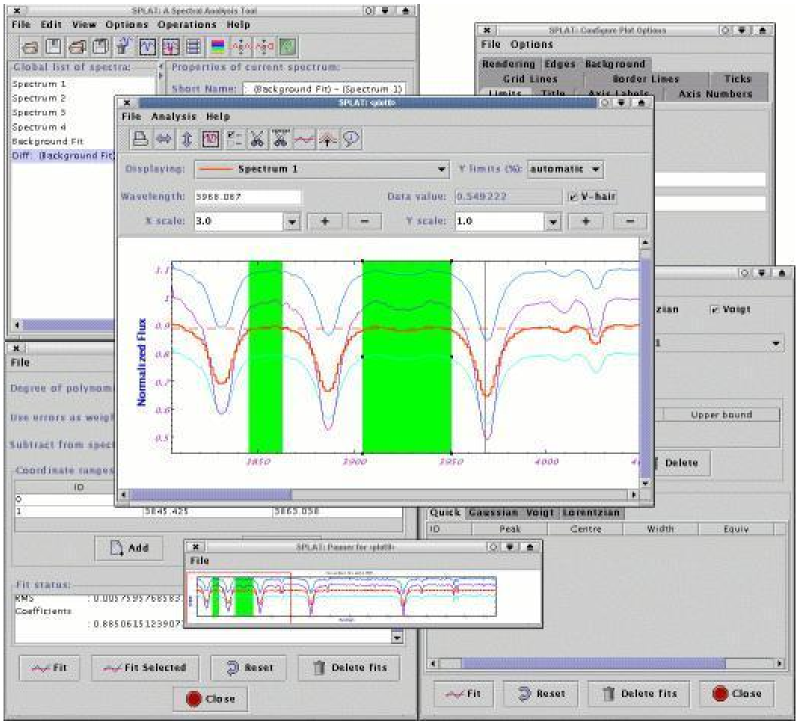
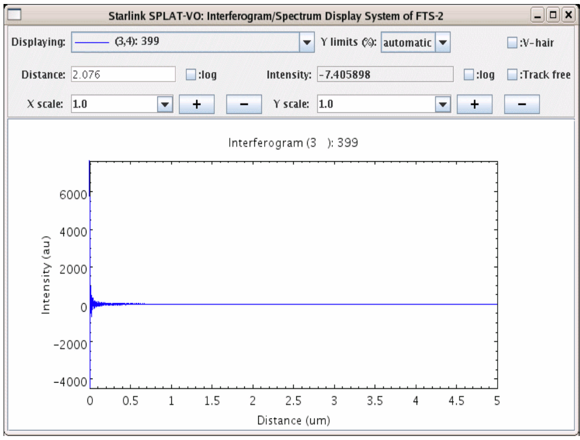
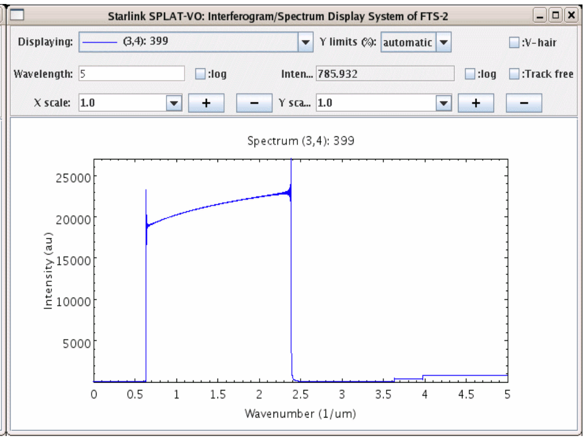


Figure 1. SPLAT spectral display tool.

For the FTS-2 QL display of the rapid scan mode, only single interferograms and the corresponding spectrum for a specific pixel will be shown by the SPLAT system. The Java class, ca.uol.aig.fts.QuickXY, implements such a display. The following two pictures show an interferogram and a spectrum displayed with this tool.





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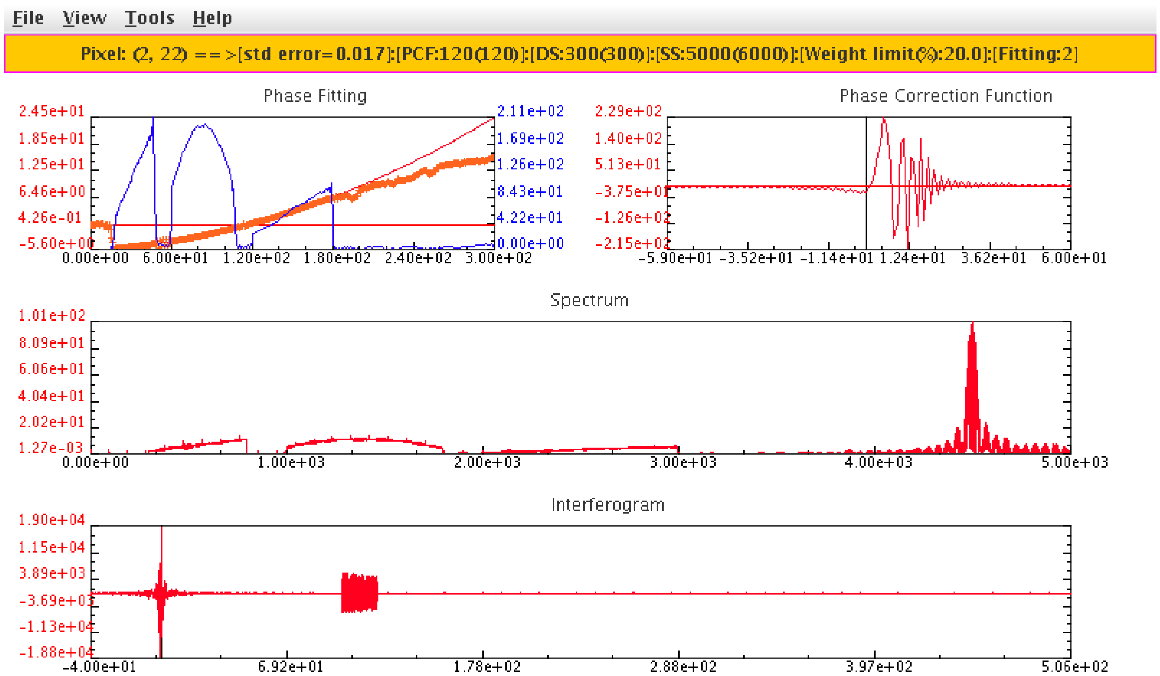
In order to fully assess the performance of the FTS data reduction, it will be necessary to look at plots of the phase correction in addition to the normal interferogram and spectrum plots. For example, the following picture shows the output of a Java program (written during the FTS pipeline development for testing purposes) plotting of the phase fitting error, the phase correction function, as well as the interferogram and spectrum for a given pixel:



4.2. 2-D display

For displaying images, such as for the SED mode QL display, the Starlink Graphical Astronomy and Image Analysis Tool (GAIA) will be used. See [Starlink User Note 214.10] for more information. GAIA provides the following features, as well as several more advanced image analysis capabilities:

- Display of images in FITS and Starlink NDF formats.
- Panning, zooming, data range and colour table manipulations.
- Continuous display of the cursor position and the image data value.
- Display of many images (clones), each in its own window.
- Coloured annotation, using text and line graphics.
- Printing of the displayed image and annotations to a postscript file.
- Real time pixel value table. A table displaying the data values and simple statistics of a region about the cursor can be displayed.

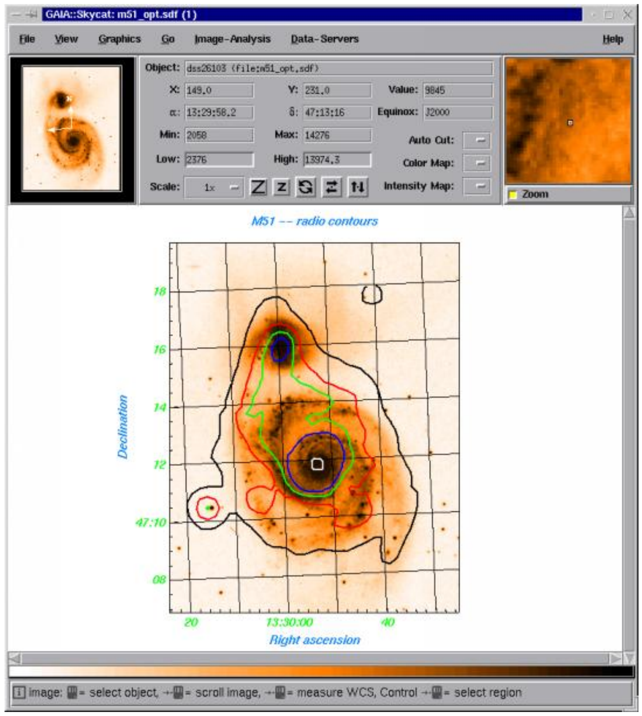
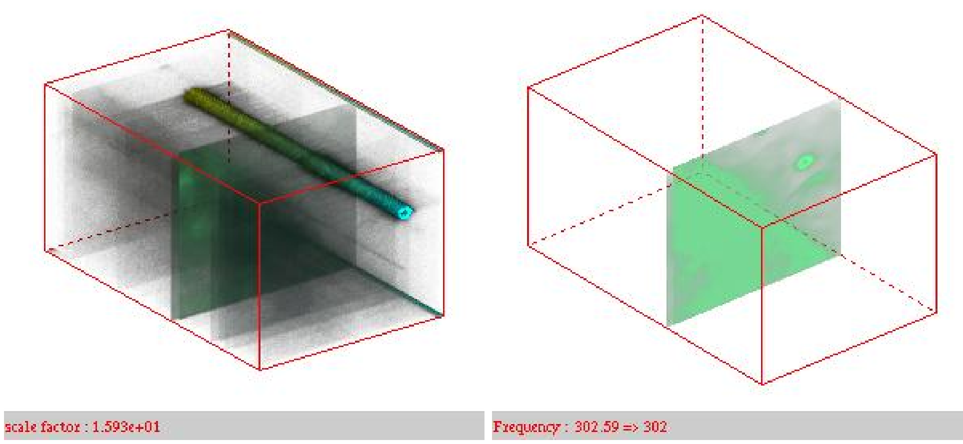


Figure 2. GAIA image display tool.

4.3. 3-D display

In order to visualise the full spectra data cubes (i.e. not in the QL mode), a 3-D display system which can display slices of the cube as well as identify features distributed across the entire cube will be useful, as illustrated in the following image. If a suitable display package is not available from the JAC, the U of L can provide the necessary code.



References

[1] Brad Gom, FTS-2 Operational Concept Definition. FTS-2 Project   SC2/FTS/SYS/004.
[2] Tahic, M. T., Fourier Transform Spectroscopy of the Orion Molecular Cloud, MSc Thesis, Chapter 5, 2004.