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SOFIA Cookbook Recipe: How to view GREAT spectra using CLASS

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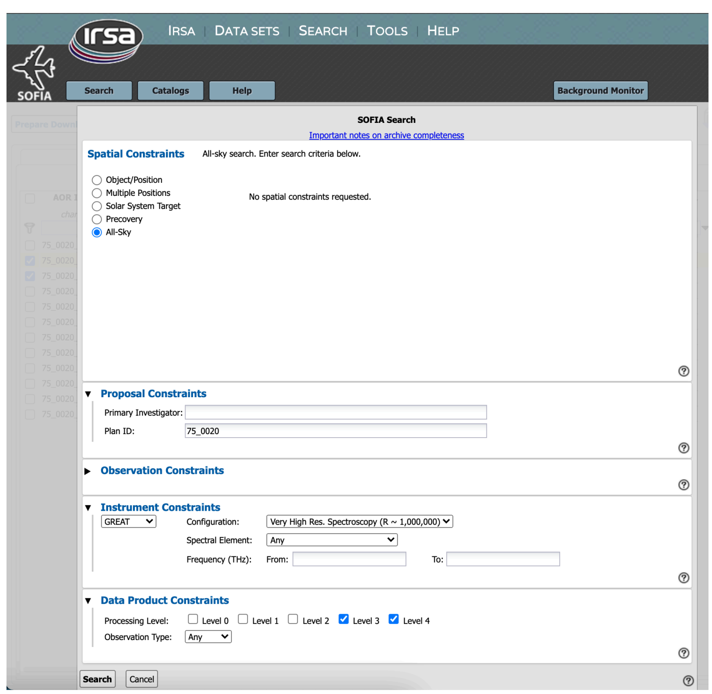
Introduction

This recipe is a beginner's introduction to plotting GREAT spectra using the `class` utility, which is part of the GILDAS package developed by IRAM and now the standard for single-dish heterodyne spectroscopy data reduction. The goal is to take you from finding a sample data set through modifying the baseline fit, averaging, and saving the result in a `fits` file.

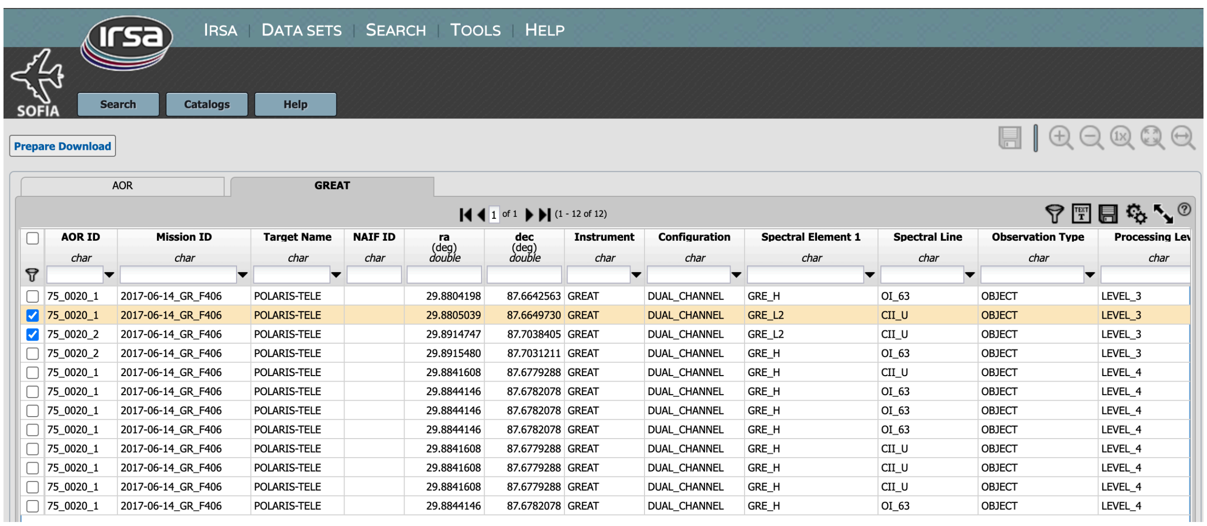
Ingredients

Data can be downloaded directly **here**, or downloaded from the ISRA archive by completing the following steps.

1. Download and install `class` from the IRAM GILDAS homepage https://www.iram.fr/IRAMFR/GILDAS/
2. Open the `class` manual in a browser tab. Also, get this useful set of tips on using `class` for reference: http://www.iram.fr/~gildas/demos/class/class-tutorial.pdf
3. Find the data: [see screenshot of archive interface]
   - Go to ISRA archive and log in
   - Click "SOFIA archive"
   - Select "All Sky"
   - Enter 75_0020 in "Plan ID"
   - Use the "Instrument" pulldown menu to select "GREAT"
   - Press <search>



4. Select and download the data [see screenshot of archive search results]
   - Select the files: (2017-06-14_GR_F406_75_0020_**1**_1900536.9.great.tar, and 2017-06-14_GR_F406_75_0020_**2**_1900536.9.great.tar
   - Press <Prepare download> and then again <Prepare download>
   - Save the zip file to a working directory and Unzip it



AOR ID	Mission ID	Target Name	NAIF ID	ra (deg)	dec (deg)	Instrument	Configuration	Spectral Element 1	Spectral Line	Observation Type	Processing Lev
char	char	char	char	double	double	char	char	char	char	char	char
75_0020_1	2017-06-14_GR_F406	POLARIS-TELE		29.8804198	87.6642563	GREAT	DUAL_CHANNEL	GRE_H	OI_63	OBJECT	LEVEL_3
75_0020_1	2017-06-14_GR_F406	POLARIS-TELE		29.8805039	87.6649730	GREAT	DUAL_CHANNEL	GRE_L2	CII_U	OBJECT	LEVEL_3
75_0020_2	2017-06-14_GR_F406	POLARIS-TELE		29.8914747	87.7038405	GREAT	DUAL_CHANNEL	GRE_L2	CII_U	OBJECT	LEVEL_3
75_0020_2	2017-06-14_GR_F406	POLARIS-TELE		29.8915480	87.7031211	GREAT	DUAL_CHANNEL	GRE_H	OI_63	OBJECT	LEVEL_3
75_0020_1	2017-06-14_GR_F406	POLARIS-TELE		29.8841608	87.6779288	GREAT	DUAL_CHANNEL	GRE_H	CII_U	OBJECT	LEVEL_4
75_0020_1	2017-06-14_GR_F406	POLARIS-TELE		29.8844146	87.6782078	GREAT	DUAL_CHANNEL	GRE_H	OI_63	OBJECT	LEVEL_4
75_0020_1	2017-06-14_GR_F406	POLARIS-TELE		29.8844146	87.6782078	GREAT	DUAL_CHANNEL	GRE_H	OI_63	OBJECT	LEVEL_4
75_0020_1	2017-06-14_GR_F406	POLARIS-TELE		29.8844146	87.6782078	GREAT	DUAL_CHANNEL	GRE_H	OI_63	OBJECT	LEVEL_4
75_0020_1	2017-06-14_GR_F406	POLARIS-TELE		29.8841608	87.6779288	GREAT	DUAL_CHANNEL	GRE_H	CII_U	OBJECT	LEVEL_4
75_0020_1	2017-06-14_GR_F406	POLARIS-TELE		29.8841608	87.6779288	GREAT	DUAL_CHANNEL	GRE_H	CII_U	OBJECT	LEVEL_4
75_0020_1	2017-06-14_GR_F406	POLARIS-TELE		29.8841608	87.6779288	GREAT	DUAL_CHANNEL	GRE_H	CII_U	OBJECT	LEVEL_4
75_0020_1	2017-06-14_GR_F406	POLARIS-TELE		29.8844146	87.6782078	GREAT	DUAL_CHANNEL	GRE_H	OI_63	OBJECT	LEVEL_4

Procedure

1. Load data into CLASS
   - Go to the directory where you put the zip file
   - Go to the directory where the unzipped data are:

```
cd sofia_2017-06-14_GR_F406/p4897/2017-06-14_GR_F406_75_0020_2_1900536.9
```

   - Start class

```
class
```

2. Open the file with calibrated main-beam temperature spectra and list them:

```
LAS> file in 2017-06-14_GR_F406_75_0020_2_1900536.9_Tmb.great
LAS> lis in
Input index contains:
 N;V Source       Line         Telescope      Lambda     Beta Sys  Sca Sub
 1;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20588 2
 2;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20588 6
 3;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20588 10
 4;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20588 14
```

etc.

3. Get the spectra of the central pixel (0):

```
LAS> set tel *0*
LAS> fin
I-FIND,  20 observations found
LAS> lis
Current index contains:
N;V Source       Line         Telescope      Lambda     Beta Sys  Sca Sub
1;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20588 2
2;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20588 6
3;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20588 10
4;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20588 14
5;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20588 18
6;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20590 2
7;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20590 6
8;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.1   +152.3 Eq 20590 10
9;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.2   +152.4 Eq 20590 14
10;4 POLARIS-TELE CII_U        SOF-LFAH_0_S    +28.2   +152.4 Eq 20590 18
71;4 POLARIS-TELE CII_U        SOF-LFAV_0_S    +26.8   +150.8 Eq 20588 2
72;4 POLARIS-TELE CII_U        SOF-LFAV_0_S    +26.8   +150.8 Eq 20588 6
73;4 POLARIS-TELE CII_U        SOF-LFAV_0_S    +26.8   +150.8 Eq 20588 10
74;4 POLARIS-TELE CII_U        SOF-LFAV_0_S    +26.8   +150.8 Eq 20588 14
75;4 POLARIS-TELE CII_U        SOF-LFAV_0_S    +26.8   +150.8 Eq 20588 18
76;4 POLARIS-TELE CII_U        SOF-LFAV_0_S    +26.8   +150.8 Eq 20590 2
77;4 POLARIS-TELE CII_U        SOF-LFAV_0_S    +26.8   +150.8 Eq 20590 6
78;4 POLARIS-TELE CII_U        SOF-LFAV_0_S    +26.8   +150.8 Eq 20590 10
79;4 POLARIS-TELE CII_U        SOF-LFAV_0_S    +26.9   +150.9 Eq 20590 14
80;4 POLARIS-TELE CII_U        SOF-LFAV_0_S    +26.9   +150.9 Eq 20590 18
```

4. Plot the first individual spectrum that was found for the central pixel. You will see the entire passband, which likely includes much more than you need to see.

```
LAS> get first
I-GET,  Observation 1; Vers 4 Scan 20588
LAS> plot
```

5. Narrow to the center of the passband near the central velocity of cloud, smooth to 0.5 km/s, and plot again. The data are now acceptable gridded and reveal the approximate range and sensitivity expected for observations of Galactic sources. The keyword "Time" in the header shows 0.28 for this individual spectrum.

```
LAS> get first
I-GET,  Observation 1; Vers 4 Scan 20588
LAS> set unit v f
LAS> set mode x -50 50
LAS> pl
LAS> smo gau 0.5
LAS> pl
```

6. Set up baseline fitting. We will do first order excluding the central portion where there could be a line.

```
LAS> ge fi
LAS> set window -50 -30 30 50
LAS> plot
LAS> draw win
LAS> base /plot
```

7. Write baseline-subtracted spectra to new file

```
LAS> file out bsub.dat single /over
I-FILE,  File is version 2 (record length: 1024 words)
I-NEWPUT,  bsub.dat initialized
LAS> write
LAS> for j 2 to found
LAS: get next
LAS: plot; base /plot; draw win
LAS: write
LAS: next j
```

8. Average the baseline-subtracted spectra from the new file, get the rms

```
LAS> file in bsub.dat
LAS> fin /all
LAS> average /resample /nocheck cal
LAS> smoo gau 0.5
LAS> plot
LAS> rms /nocheck
```

9. Write final spectrum to FITS file

```
LAS> fits write bsub.fits /mode spectrum
```

Cleaning up

Now that you have cooked this simple recipe, you should be able to expand and make the spectra you and your colleagues have been dreaming of. To get some more ideas, look at the `class` script in the `tar` file for the full reduction script that was used in generating the products and for comments and examples of how to do things with GREAT data in class.