SOFIA Cookbook Recipe: How to view GREAT spectra using `CLASS`

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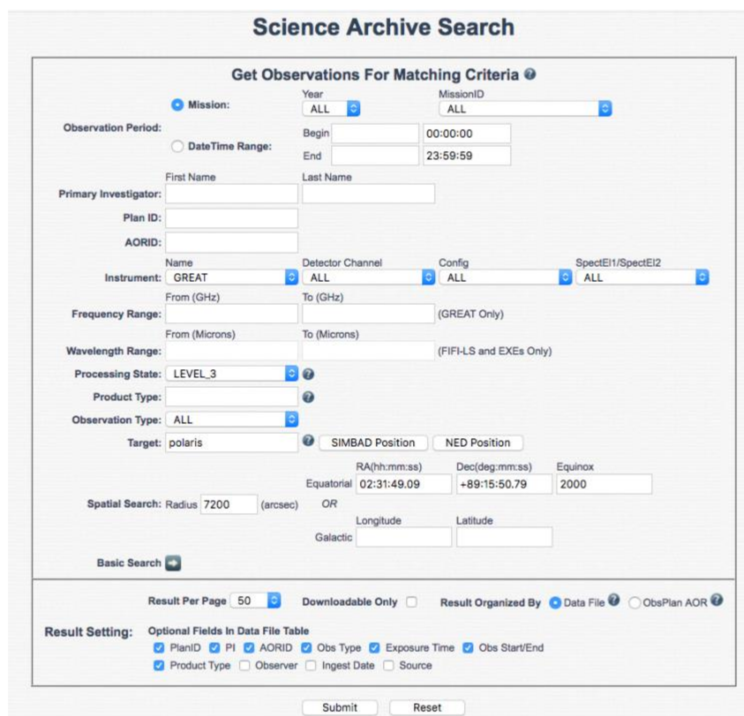
Introduction

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

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 DCS archive, https://dcs.sofia.usra.edu/ and log in
   - Click "Search Science Archive"
   - Click "Advanced search"
   - Enter 75_0020 in "Plan ID"
   - Use the "Instrument" pulldown menu to select "GREAT"
   - Enter "Polaris" in the "target" text field, press "SIMBAD Position"
   - Enter "7200" in the "search radius" text field
   - Press <submit>



4. Select and download the data [see screenshot of archive search results]
   - There are 4 entries returned. Looking at the “Frequency” column of the output, you can see two are for the CII line (1900.53 GHz) and two are for OI (4744.78 GHz).
   - Check the box at the left for the two that are on the CII line.
   - Press <Get Selected Data in Current Page>
   - Watch for an email from “The SOFIA Data Cycle System”, then click the link in the email to save the ZIP file with your data
   - Move the zip file to a working directory and Unzip it

Get Selected Data In Current Page | Get Downloadable Data In All Pages | There is a ***30GB*** download limit.

	ObservationID	MissionID	PlanID	PI	AORID	Instrument	Frequency (GHz)	Detector Channel	Config	SpectEl1	SpectEl2	Slit	Target	ObsType	Processing
☐	2017-06-14_GR_F406_75_0020_2_4744777.49.great.tar	2017-06-14_GR_F406	75_0020	Yorke, Harold	75_0020_2	GREAT	4744.78		DUAL_CHANNEL	GRE_H	NONE		POLARIS-TELE	OBJECT	LEVEL_3
☑	2017-06-14_GR_F406_75_0020_2_1900536.9.great.tar	2017-06-14_GR_F406	75_0020	Yorke, Harold	75_0020_2	GREAT	1900.54		DUAL_CHANNEL	GRE_L2	NONE		POLARIS-TELE	OBJECT	LEVEL_3
☑	2017-06-14_GR_F406_75_0020_1_1900536.9.great.tar	2017-06-14_GR_F406	75_0020	Yorke, Harold	75_0020_1	GREAT	1900.54		DUAL_CHANNEL	GRE_L2	NONE		POLARIS-TELE	OBJECT	LEVEL_3
☐	2017-06-14_GR_F406_75_0020_1_4744777.49.great.tar	2017-06-14_GR_F406	75_0020	Yorke, Harold	75_0020_1	GREAT	4744.78		DUAL_CHANNEL	GRE_H	NONE		POLARIS-TELE	OBJECT	LEVEL_3

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.