

ALMA spectrum cookbook

Magnus Persson, Mihkel Kama & Daniel Harsono

Aims

ALMA datacubes provide a wealth of spatially resolved information on many lines of many species. The analysis process needs to be standardized and automatized to make the exploitation of these large datasets practical. Starting from a FITS cube, we want to be able to extract a single spectrum, and to identify and measure lines in that spectrum. Repeating this operation, we want to produce moment maps of an arbitrary line, and N_{tot} and T_{ex} maps for an arbitrary species with at least two lines in the spectral range (only for pixels where ≥ 2 lines are detected). It should be possible to obtain “quick look” maps of moments, column density, and excitation temperature with minimal manual involvement.

Technical implementation

The pipeline of scripts is written in Python, and all steps except line identification can be carried out with Python scripts. Each dataset will require the user to go and actually look at what lines of what species are there, however. The most powerful, and freely available, tool for line identification is CASSIS. One important component is the ease of creating CASSIS-readable spectra, and outputting ASCII-format lists of identified or even measured lines. Once a list of species or lines of interest is in place (could also be *a priori*, e.g., “give me all methanol lines”), an entire datacube can be automatically analyzed and plots produced.

Quick overview of steps involved

These steps have been verified on the Leiden Observatory (Strw) workstations on 2016-03-25.

1. [Download and unpack example data.](#)
2. [Open image cube\(s\) in casaviewer.](#)
3. [Mark region \(rectangle/point/polygon\).](#)
4. [Open the spectral profile for region.](#)
5. [Change axis units to frequency\(x-axis, GHz\) and Kelvin \(y-axis\).](#)
6. [In the spectral profile window, save the profile to a text file and exit.](#)
7. [Open the casa_to_cassis.py script.](#)
8. [Edit the input/output file names and the system velocity.](#)
9. [Run the script from terminal.](#)
10. [Read the CASSIS start guide/documentation](#)
11. [Start CASSIS](#)
12. [Line identification and fitting](#)
13. [Getting to science: moments and maps](#)

Steps in depth

Download and unpack example data.

The data we will work with in this example is here:

<https://drive.google.com/open?id=0B1pInHC55cq9V2h3Uzk1MnU1YVU>

The file, `afgl4176.contsub.image.tar.gz`, is 5 MB. Unpack it.

The data is from an ALMA project (2012.1.00469.S, PI: Johnston), the accompanying paper is Johnston et al. 2016, ApJ, 813L, 19J

(http://adsabs.harvard.edu/cgi-bin/bib_query?arXiv:1509.08469)

You can download the pdf here:

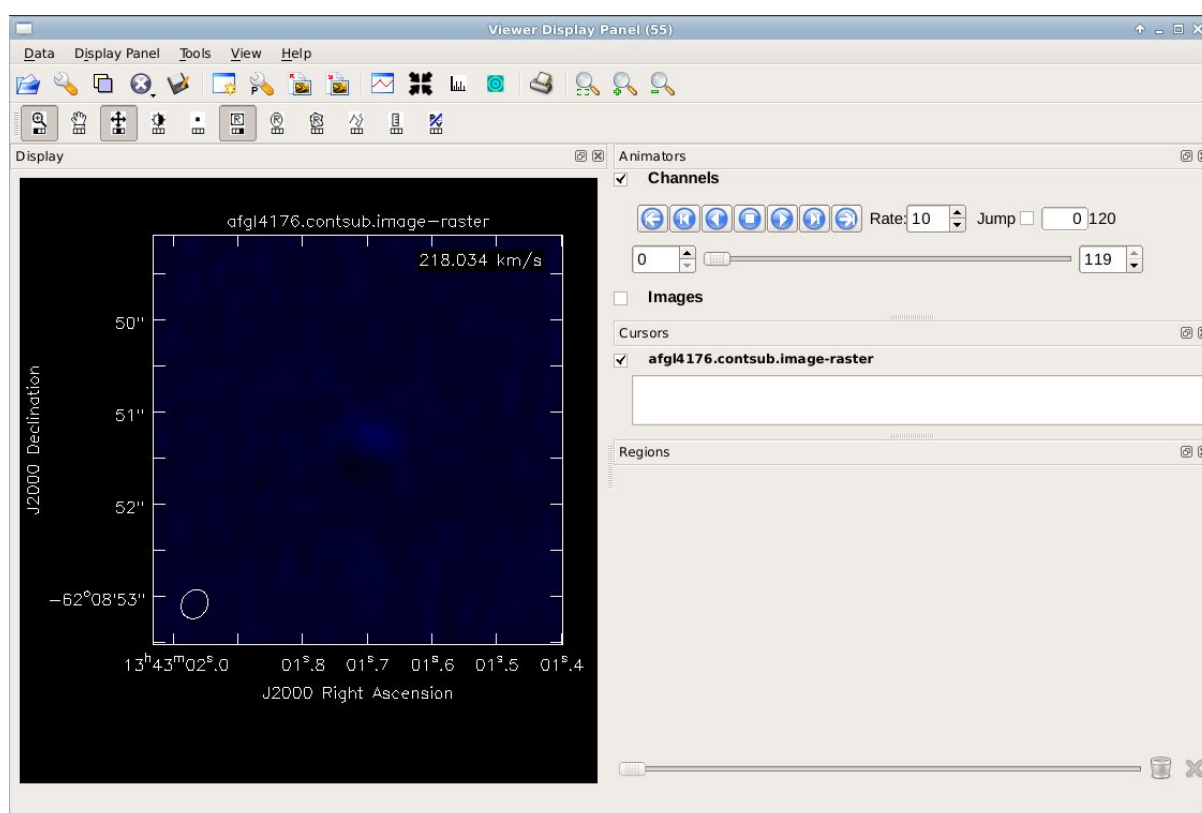
<https://drive.google.com/open?id=0B1pInHC55cq9ZnZoUEVERDVWcmM>

Casaviewer

Run

```
casaviewer aagl4176.contsub.image
```

to open the unpacked image in this example in the casaviewer. It should now look like this.



We will now mark a region, look at the spectrum and save it to a text file.

Mark region (rectangle/point/polygon).

In the toolbar you have several different tools, feel free to test them. There are four different ways to mark regions.



They are for marking a point/rectangle/circle/polygon region

To mark a point region, left or right click the point symbol (leftmost in figure)

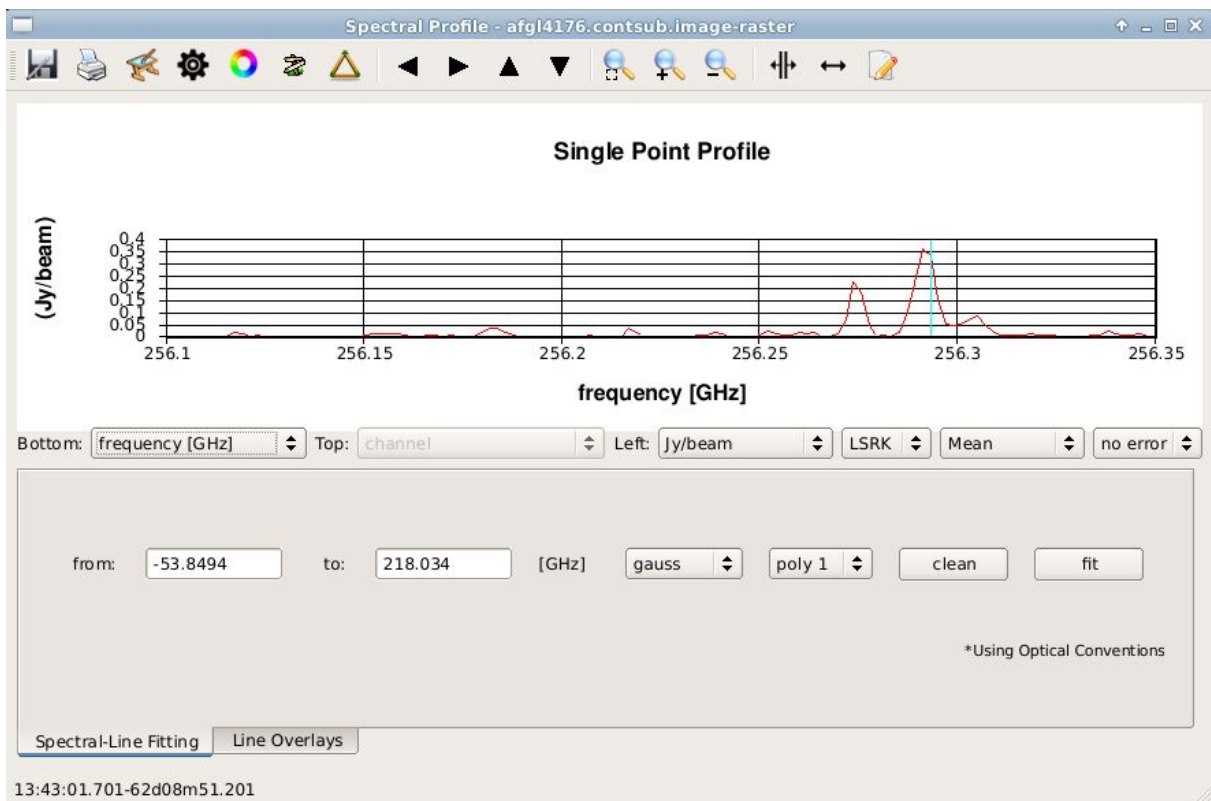
Click in the image where you want to extract the spectrum, a small symbol will appear.

Open the spectral profile for region.

Now we want to look at the spectral profile of this point. To do this click the spectral profile symbol in the toolbar of the main window.

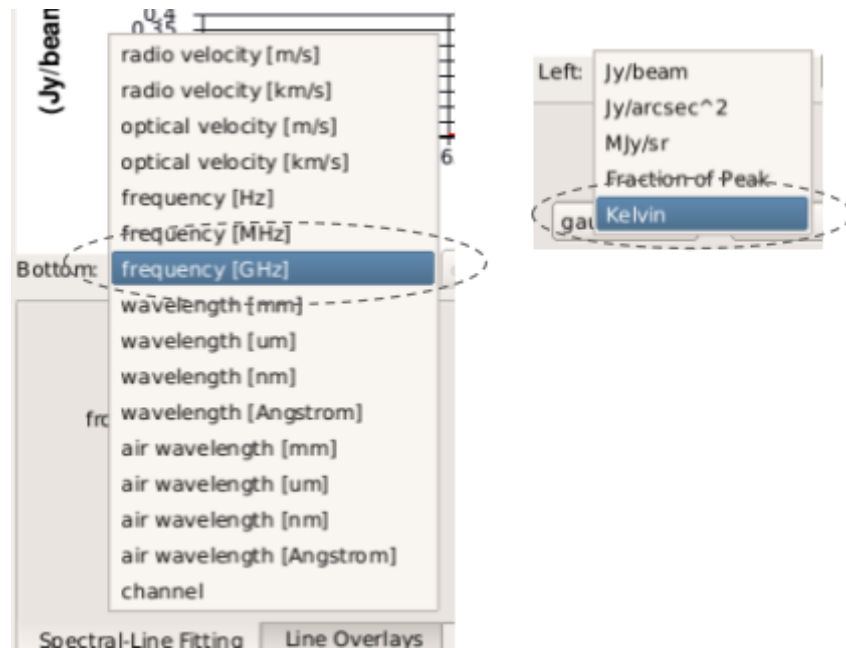


Since you have a region selected in the main window (the point) the window that pops up will show something like this (if you choose something in the center of the image).

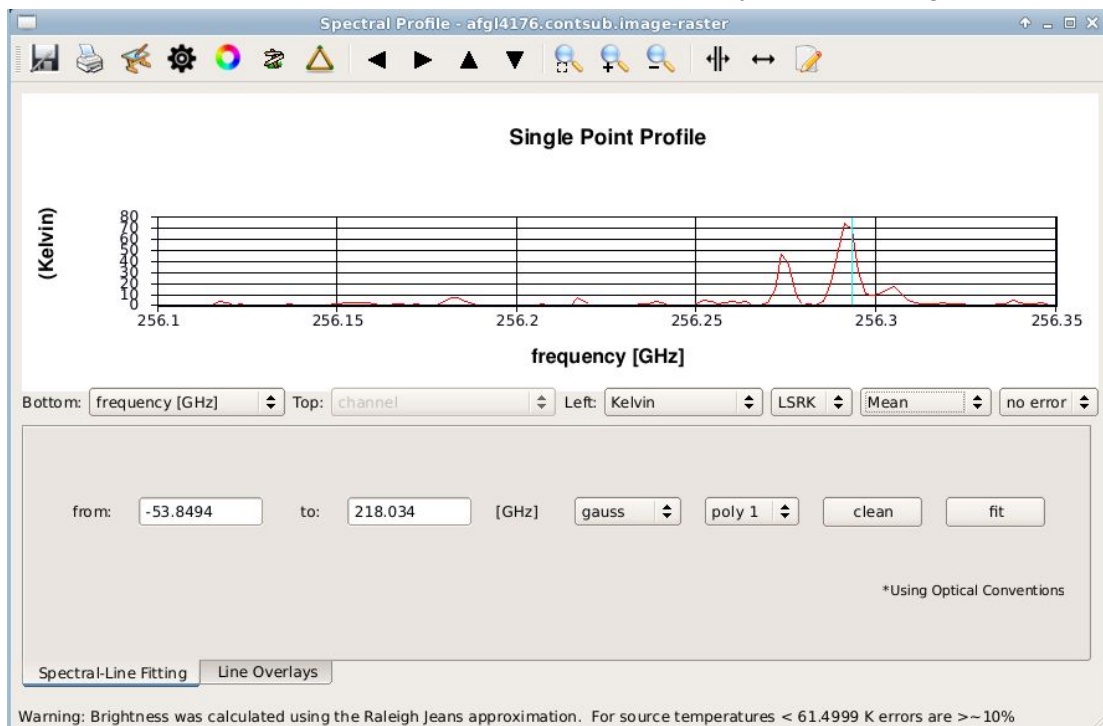


Change axis units to frequency (x-axis, GHz) and Kelvin (y-axis)

Before we save the spectral profile from the marked region, we need to change the axis units to GHz and Kelvin. In the drop down menus below the profile, change to the right units.



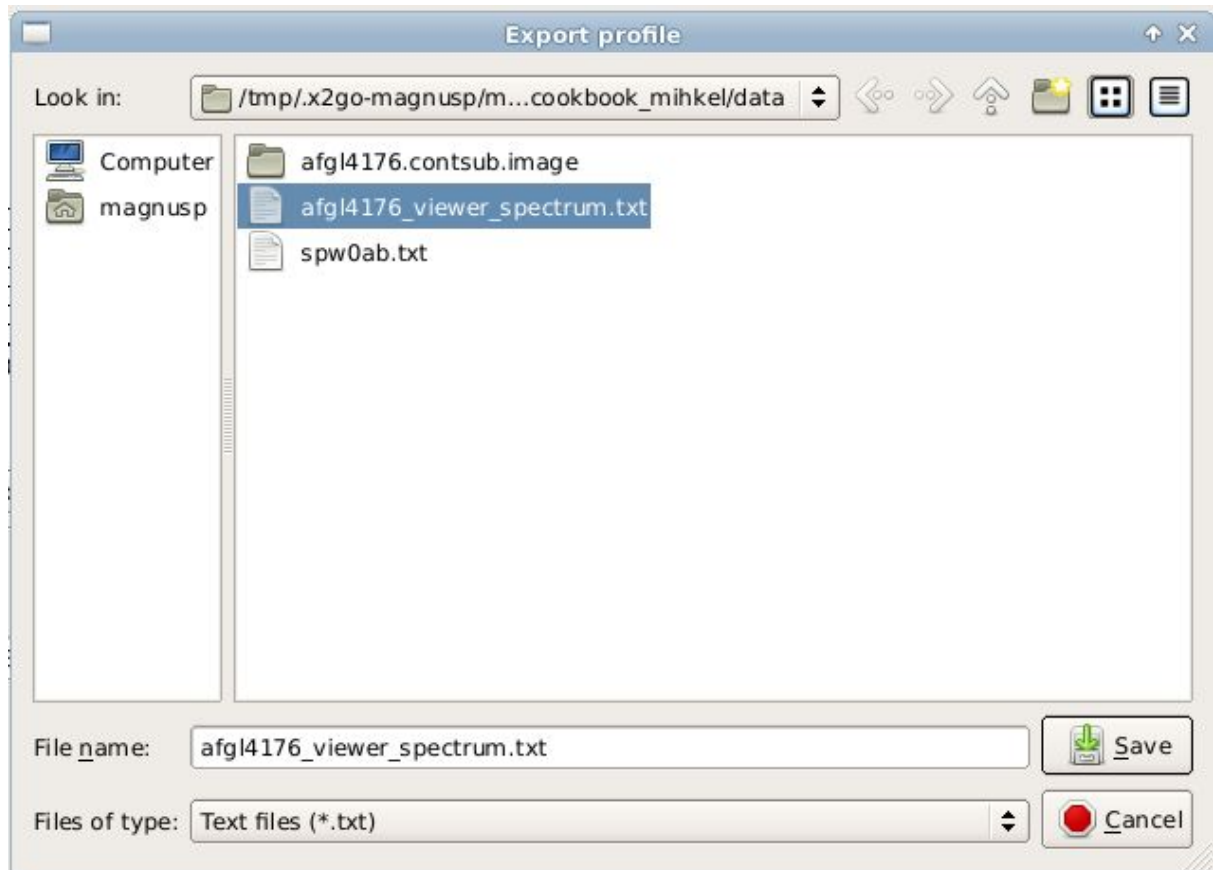
Should now look something like this. You can move your selection in the main casaviewer window around, and this window will update. You can also try a different region selector.



In the spectral profile window, save the profile to a text file.
Now to save the spectrum in a text file, press the save symbol



and specify the name and path to where you want to save your ascii spectrum.



Exit casaviewer.

Open the 'to_cassis_from_casaviewer_txt.py' script.

The script relies heavily on Astropy, so you need that installed. The workstations at strw have it, so don't worry about that.

Edit the input/output file names and the system velocity.

Find the lines at the beginning of the script shown in the figure below.

```
path = '/path/to/folder/'
file_spectra = 'casaviewer_spectral_profile.txt'
# Vlsr of source
vlsr = -52 * u.km/u.s
# name of output file
outfile = 'cassis_spectrum_file.fus'
```

Edit them according to your needs and preferences.

Run the script from terminal in same folder.

```
> python to_cassis_from_casaviewer_txt.py
```

CASSIS quick start

The CASSIS general documentation can be found at <http://cassis.irap.omp.eu/> and click on 'Documentation'. This is just a quick introduction to get you going. There are video tutorials as well:

http://cassis.irap.omp.eu/help/?page=html/video_tutorials

The User manual contains several important sections, please read through:

Modules:

- Spectrum Analysis

- LTE+RADEX

- Line Analysis

- Rotational diagram

Common functionalities:

- Interactive graphical tools

- Inspect and analyze the spectrum

and of course you should look at

"Caveats and tricks"

CASSIS

Start CASSIS.

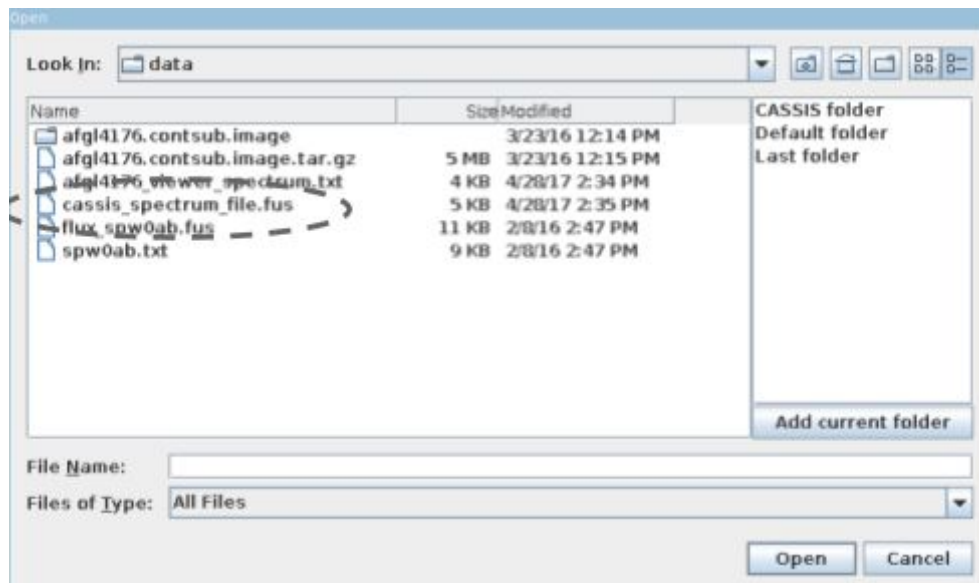
```
> cassis 1048
```

for 1048 MB of memory reserved.

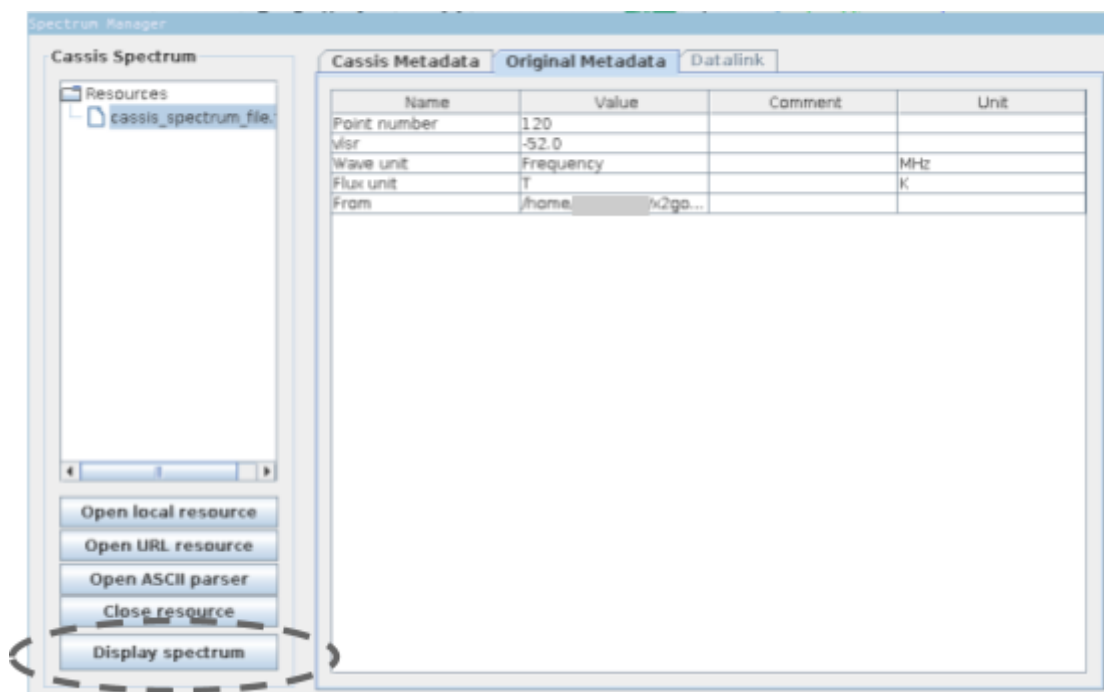
Open the spectrum .fus file by clicking the open icon



a window pops up



Open your .fus file (cassis_spectrum_file.fus in this example) by selecting it and pressing "Open". After this a new window pops up.



Ideally you start by clicking 'Display spectrum Analysis'. You can have multiple spectra open in the manager and use this to switch between them. After clicking "Display spectrum" another windows pops up



In this window you **check** that the file you want is listed in the **path next to the Load button**, also **check** that the correct **Vlsr** and **frequency range** have been read from the file we created with the script. Now you should also **define** what **telescope (resolution)** is relevant for the data. For this practice data it is ALMA with 0.3 arcsecond resolution at ~ XXX GHz, this means a representative baseline of around 900 m. If you **click** the **'???' button** next to 'Telescope' you will see that there is no file for ALMA 900. You have to create your own file.

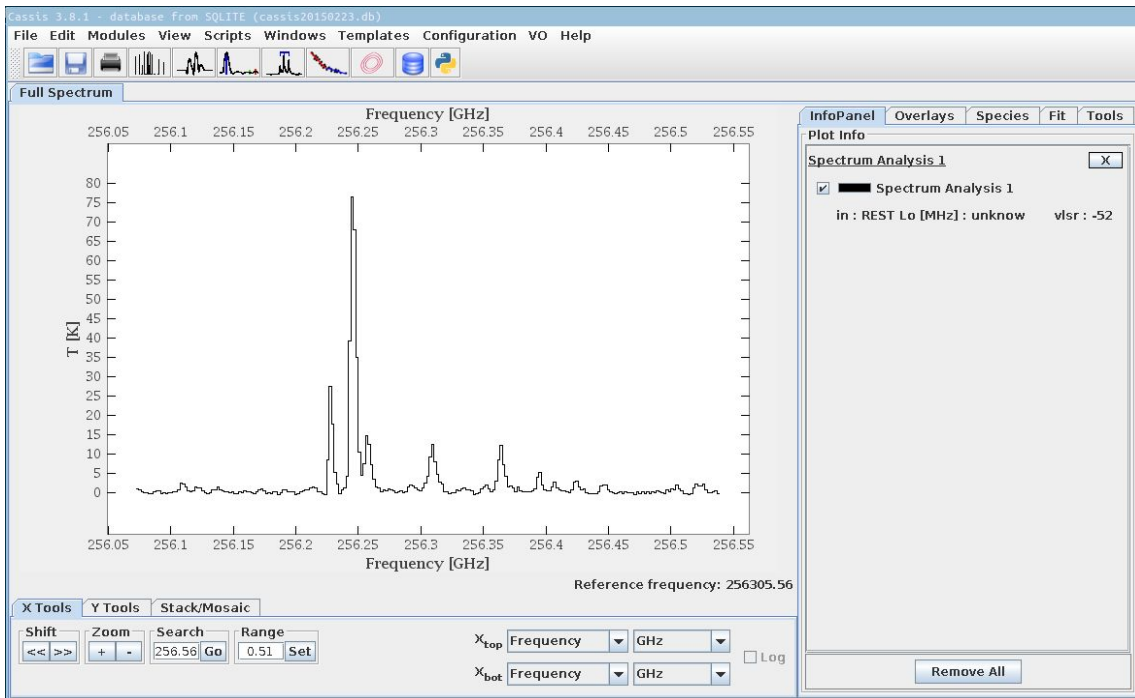
Go to the directory where you have CASSIS installed and go to the telescope directory (/path/to/cassis/delivery/telescope), and copy to your home directory one of the ALMA files (or if it is a local install, you can just copy the file in the same folder).

```
// Diameter (m)
500
// Frequency (MHz), Beam efficiency, IF (GHz), LSB gain (%), USB gain (%)
4.5000e+05 1.0000 16.000 1.0000 1.0000
4.5500e+05 1.0000 16.000 1.0000 1.0000
4.6000e+05 1.0000 16.000 1.0000 1.0000
4.6500e+05 1.0000 16.000 1.0000 1.0000
: : : : :
1.9350e+06 1.0000 7.2000 1.0000 1.0000
1.9400e+06 1.0000 7.2000 1.0000 1.0000
1.9450e+06 1.0000 7.2000 1.0000 1.0000
1.9500e+06 1.0000 7.2000 1.0000 1.0000
```

Change the diameter to 900, and save the file with a different file name, say alma_900, to a place where you have write permissions and you can find it easily.

Now you can load your new telescope file into CASSIS and then you press "Display" in the load dialogue.

That is it, the main CASSIS window will now show you spectrum.



Now you can start the interesting part, the spectrum analysis. These can be found in the CASSIS documentation.

Line identification and fitting

These things should be covered in the CASSIS documentation

- Species identification: how to go through all lines of a species that match given constraints.

- Line identification: how to overlay all lines of all species that match given constraints, to find the most likely match for a given feature.

- Fit gaussian(s) and save the fit parameters in a linelist

Getting to science: moments and maps

These things should be covered in the CASSIS documentation

- Rotational diagrams in CASSIS for a given line list.

- Moment maps using Jessica's scripts.

- Table of column densities and T_{ex} for interesting positions