Basic CLASS Cookbook

René Plume - University of Calgary

Aug 2006

Contents

1 Getting CLASS

The CLASS software can be downloaded from the IRAM website at http://iram.fr/ . It is available for many different platforms, including MAC OS X (yay!).

2 Getting Started

Once installed and running you should see the following prompt:

LAS>

If a graphics display window did not open automatically, open one manually by typing:

LAS> dev xa

the CLASS HELP files can be accessed by typing:

LAS> help

Note however, the CLASS commands are not always obvious! You may have to hunt to find what you're looking for.

3 Input and Output Files

to open a data file type:

LAS> file in *filename*

To create a NEW output file (i.e. a brand new, empty file with nothing in it yet), type:

LAS> file out *filename* new

where *filename* is the name of the file (e.g. output.dat). NOTE - once this file has been created using the new option, you never need to use the new option again for this file. i.e. to open an old output file that you had previously created, type:

LAS> file out *filename*

File names and other options are "sticky" in that they are remembered until you overwrite them. Thus, CLASS will remember the input and output file names until you manually change them or exit the program.

4 Plotting Spectra and Fitting Gaussian Line Profiles - Example 1

Once you have opened an input file (try opening the datafile called test1.dat) with data now you need to find all the data in the file and place it in the register so type:

LAS> find

and then

LAS> LIS

to list all the spectra in the register. You should now see the following on your screen:

I-LISTE, Current index :
1243; 3 W43S CS5-4 CSO 50MHz 0.0 +30.000 Eq 1243
1239; 3 W43S CS5-4 CSO 50MHz 0.0 0.0 Eq 1239
1247; 4 W43S CS5-4 CSO 50MHz 0.0 +60.000 Eq 1247
1251; 3 W43S CS5-4 CSO 50MHz 0.0 +90.000 Eq 1251
1255; 3 W43S CS5-4 CSO 50MHz 0.0 -30.000 Eq 1255
1259; 4 W43S CS5-4 CSO 50MHz 0.0 -60.000 Eq 1259
1263; 3 W43S CS5-4 CSO 50MHz -30.000 0.0 Eq 1263
1267; 3 W43S CS5-4 CSO 50MHz -60.000 0.0 Eq 1267
1271; 3 W43S CS5-4 CSO 50MHz +30.000 0.0 Eq 1271
1275; 3 W43S CS5-4 CSO 50MHz +60.000 0.0 Eq 1275

The first two numbers are the scan number and version number, "W43S" is the source name, "CS5-4" is the molecular species and line, "CSO 50MHz" indicates the telescope and/or spectrometer used, the next number is the RA offset of the observation, and the following number is the DEC offset. IN this case the offsets are in arcseconds but you can change the units by using the "set angle" command (e.g. "set angle m" to put the units into arcminutes).
Look at the second scan by typing :

LAS> get 1239

LAS> plot

You should now see the spectrum in Figure 1.
Data are rarely perfect and often have a DC offset or a slope to the baseline. These can be removed by fitting a polynomial baseline to the spectrum. First however, you have to define the region over which the spectral line exists (i.e the region that will be excluded from the polynomial fit). In Figure 1 , the line (including line wings) can be seen to extend from $\sim 85 km/s$ to $\sim 110 km/s$. Thus we define the window containing the line by typing:

LAS> set window 85 110

A 1st order baseline can now be subtracted by typing:

LAS> base 1

or bas n where n is the order of the polynomial. The following text should appear on your screen following the "base 1" command:

I-POLYNO, Polynomial baseline of order 1 r.m.s. is 0.115 K

I-POLYNO, Area 39.29 Pos. 97.86 Width 5.94

This provides you with the 1σ rms noise level of your spectrum, as well as the area under the line (i.e. the addition of all the channels within the defined window) in K km/s, and the estimated VLSR and FWHM of the line (in km/s).
We can also fit a Gaussian to the spectrum by typing:

LAS> gauss

The following text will appear:

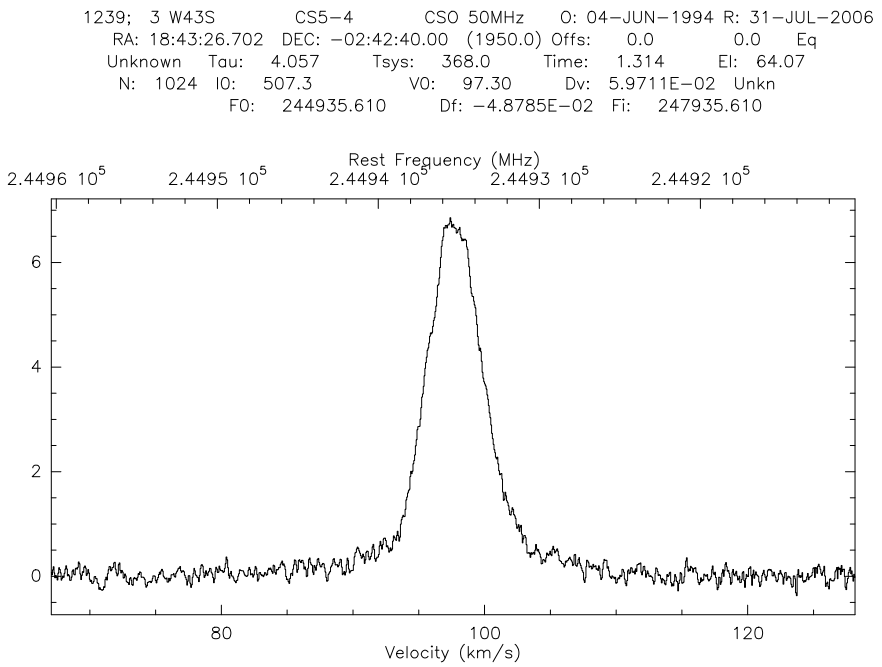

Figure 1: The CS 5-4 spectrum of W43S taken at the CSO

Guesses: 39.3 97.4 5.45
SIMPLEX Minimization has converged
RMS of Residuals : Base = .13 Line = .25
HESSE Second derivative matrix inverted
MIGRAD Fails to find improvement
MIGRAD Minimization has converged
RMS of Residuals : Base = .16 Line = .22

FIT Results
Line Area Position Width Intensity
1 36.248 (0.133) 97.759 (0.009) 5.123 (0.023) 6.6474

This provides the integrated intensity of the line in (K km/s) and the error (in parentheses), the VLSR (in km/s) and (error), the FWHM line width (in km/s) and (error) and the T_A^* peak line intensity (in K). You can see your fit by typing:

LAS> fit

You could even fit multiple gaussians to the same spectrum (if you wanted to fit the line wing emission in seen in Figures 1 and 2) by using the command:

LAS> line 2

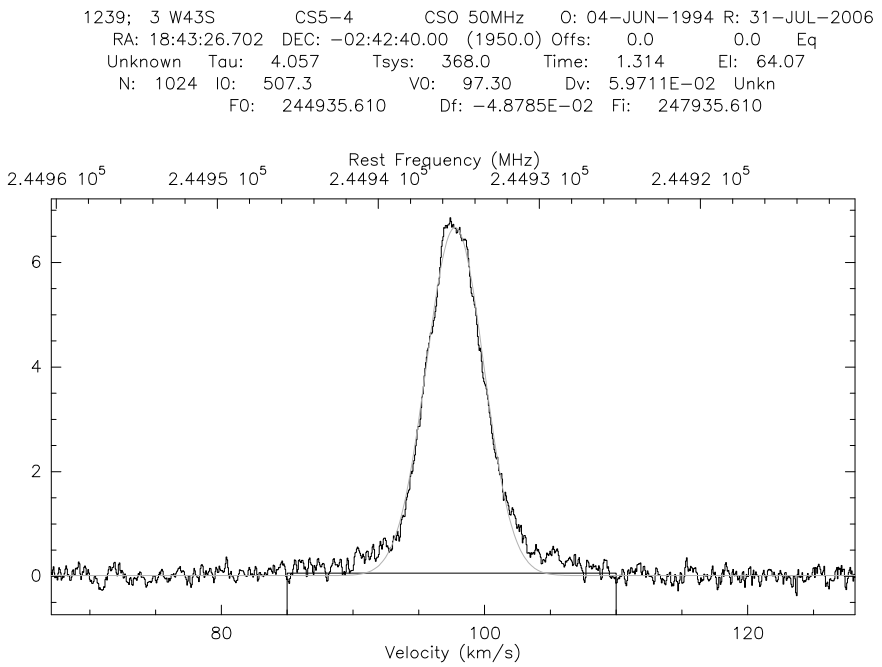

Figure 2: Result of the Gaussian fit to the CS 5-4 line

The following text will appear on your screen:
Line 1 : 0 0.000 0 0.000 0 0.000 Line 1 :
Now type something like

0 6 0 97 0 5

There are 3 grouping of numbers. The first group (0 6) corresponds to the line intensity. The leading 0 means "guess this value" and the 6 means "starting at about an intensity of 6 K". The second group (0 97) corresponds to the velocity of the line center. Again the leading 0 means "guess this value" and the 97 means "starting at about a VLSR of 97 km/s". The final grouping (0 5) corresponds to the FWHM line width. Again the leading 0 means "guess this value" and the 5 means "starting at about a FWHM of 5 km/s". In all cases, the leading 0 could be replaced by a 1. The 1 indicates that this value is fixed in the Gaussian fitting procedure.
After entering the above numbers, the next bit of text will appear:
Line 2 : 0 0.000 0 0.000 0 0.000 Line 2 :
Now enter your guesses for the 2nd gaussian (in this case the line wings). Try something like:

0 1 0 97 0 15

Now type

LAS> gauss

and you will see:
Guesses: 31.9 97.0 5.00
16.0 97.0 15.0
SIMPLEX Minimization has converged
RMS of Residuals : Base = .12 Line = .16
HESSE 1 Non-positive diagonal elements
MIGRAD Terminated without convergence
MIGRAD Covariance matrix is not positive-definite (5) times.
W-FITGAUSS, Solution not converged
RMS of Residuals : Base = .12 Line = .16

FIT Results
Line Area Position Width Intensity
1 27.523 (0.102) 97.734 (0.060) 4.320 (0.060) 5.9855
2 13.660 (0.102) 98.188 (0.060) 15.418 (0.060) .83233

and
LAS> fit

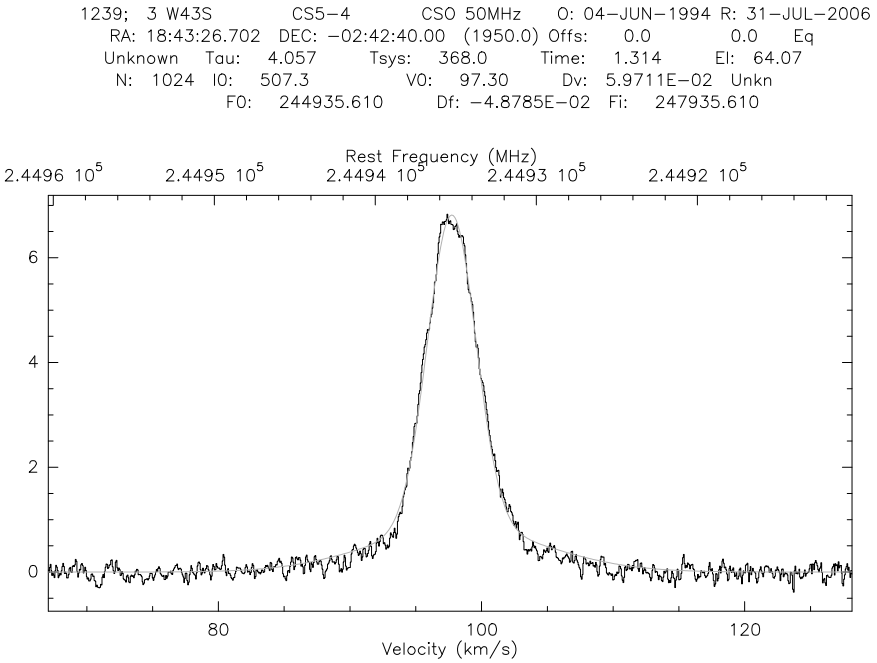

Figure 3: Result of fitting two Gaussians to the CS 5-4 line

to see the new fits (Figure 3). Or fit 1 and fit 2 to see the individual Gaussians. To

return to the mode where, by default you fit a single Gaussian and the program guesses all parameters, type:

LAS> line 0

Now to save your work (baseline subtraction, gaussian fits etc.) to your selected output file, simply type:

LAS> write

The data and fits will be saved to the output file and can be recovered by opening the outputfile using the "file in" command. Results of the Gaussian fits can be printed to screen or to an ascii file by using the:

LAS> print fit

command. Use the "help print" command to see the listing of the column headings.

5 Making Spectral Line Maps - Example 2

You can make a "postage stamp" map of all the spectra in your register quite easily to see how the spectra change from position to position. First, however, you need to fix the X and Y axis of your spectra. By looking at scan number 1239 (in Figure 1) we can figure we can use an X-axis from 70 km/s to 125 km/s and a Y-axis from -0.5 K to 7 K. To set these, type:

LAS> set mode x 70 125

LAS> set mode y -0.5 7

Typing:

LAS> map /gr

will yield the image seen in Figure 4.

6 Co-Adding Spectra - Example 3

Often, to increase signal-to-noise you will make multiple observations of the same molecular species/line and position. These then need to be coadded to produce the final spectrum. As an example, open the file "test2.dat" as an input file:

LAS> file in test2.dat

LAS> find

There will be 625 spectra in this file. If you do a "LIST" you can see them all and you can see that there are different sources, different molecular lines and different positions. Let's say that you are only interested in the source S140. We can select a single source by typing:

LAS> set source s140

LAS> fin

now there are only 463 observations in the register. Now suppose we are only interested in the neutral carbon line or CI1-0 line . We can select this by typing:

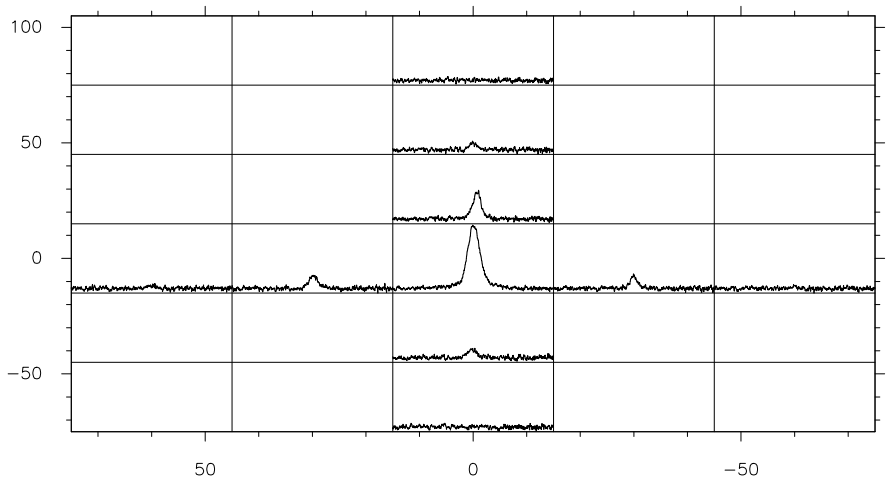

Figure 4: "Postage stamp" map of the CS 5-4 line in W49S

LAS> set line ci1-0
LAS> fin

Now there are only 194 observations in the register. Finally, suppose you only want to look at a single position, say the central (or 0 0) position. We can select this by typing:

LAS> set off 0 0
LAS> fin

Now there are 53 observations in the register. Look at a single spectrum, say the first one:

LAS> get first
LAS> plot

The spectrum is not very impressive and looks very noisy (it should be with a system temperature of 5024 K and only 1.971 minutes of integration). You can measure the noise by subtracting a baseline:

LAS> set window -12 -2
LAS> base 1

and should find that the 1σ rms noise is 1.53 K (see Figure 5).

To improve the signal-to-noise we can coadd all the spectra now in the register. Tis is done by simply typing:

LAS> sum

Figure 6 shows the result of the coadd after subtracting a baseline. The total integration

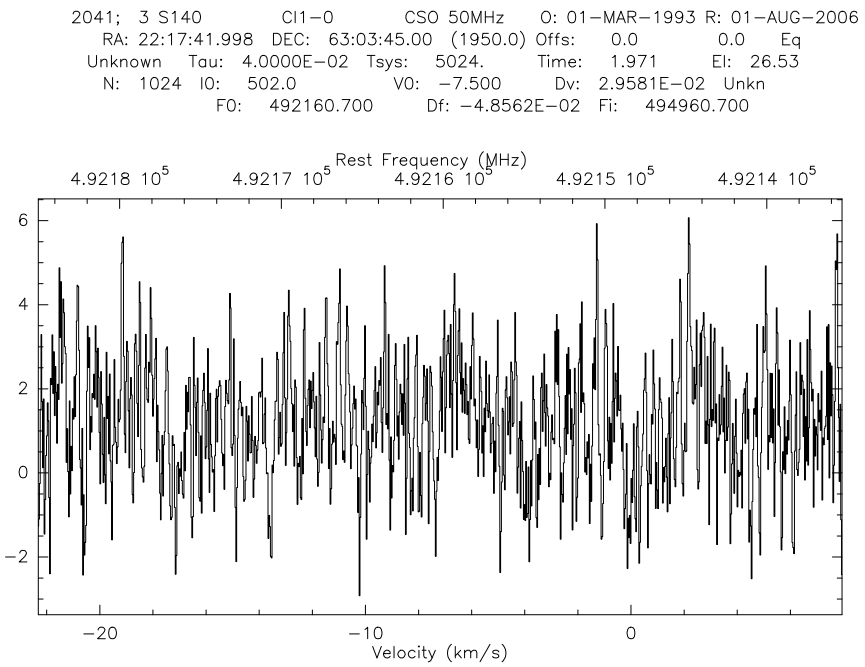

Figure 5: A single CI1-0 spectrum at the center of S140 with a 1σ rm noise of 1.53 K after 1.971 minutes of integrateion

time is now 67.99 minutes and the 1σ rms noise is improved to 0.128 K. The neutral carbon spectrum is now clearly visible.

7 Making Postscript Figures

To make a postscript figure of the "plot" window. Type:

LAS> hard *filename.ps* /dev ps fast

8 Macro Files

You can also automate your data reduction process by creating "macros". Macros are a series of CLASS commands put together in a fortran-like format to run a series of data reduction steps. The included file reduce.class (reproduce below) is an example of a macro. Comment statements in the macro are delineated by the ! character. To run this macro, type:

LAS> @reduce

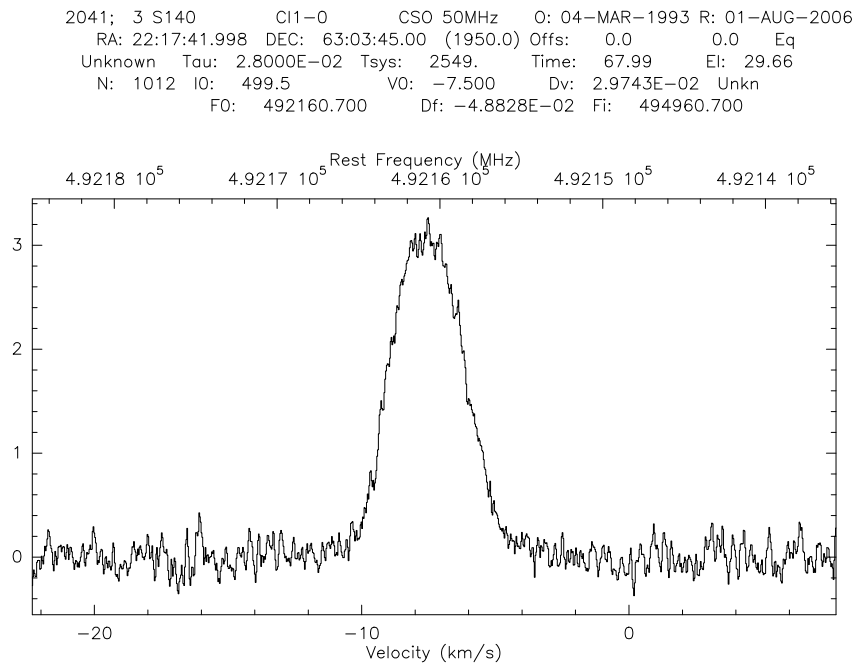

Figure 6: A co-added CI1-0 spectrum at the center of S140 with a 1σ rm noise of 0.128 K after 68 minutes of integration

set ang m ! use arcminutes
set match 0.5 ! find everything within 0.5 arcmin of the selected position

sys “rm test3.red” ! remove any old copies of the output file
file out test3.red new ! open a fresh output file
file in test2.dat ! open the input file
set source s140 ! select the source
set line ci* ! select the line
set wind -12 -2 ! set the window for base line subtraction

fin /all
for k -16 to 16 by 2 ! begin a loop in RA offset
for l -16 to 16 by 2 ! begin a loop in DEC offset
set off k l ! set the offset
find /all
if (found.ne.0) then ! if data exist at this position continue
lis

```
sum ! coadd the data
smooth box 4 ! smooth the data by 4 channels to improve S/N
base 1 /pl ! remove baseline
plot
draw win ! show the window used
! pause "Type C to continue....." ! a pause command (edited out)
write ! write date to output file
endif
next
next ! end the loop

set off * * ! reset the offsets to find every position
file in test3.red ! open the output file as the new input file
find
set mode x -18 6 ! set the x-axis limits
set mode y -0.5 7 ! set the y-axis limits
map /gr ! map the spectra

set ang s ! reset the units to arcseconds
set match 2 ! find everything within2 arcsecs
set mode x tot ! reset x-axis to the full bandpass
set mode y tot ! reset the y-axis to autoscale
```